MACHINE DESIGN

April 1954

UNIVERSITY OF MICHIGAN
APR 1954
ENGINEERING LIBRARY

DESIGNING WITH ADHESIVES

Contents, Page 3

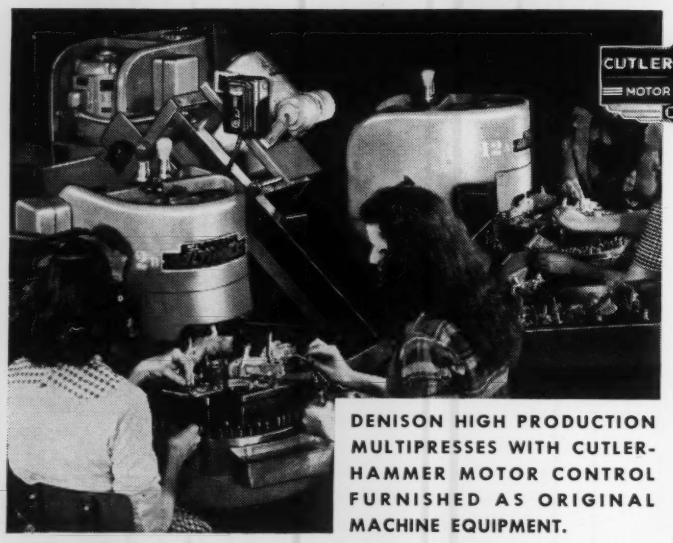
ELSWORTH

CUTLER-HAMMER

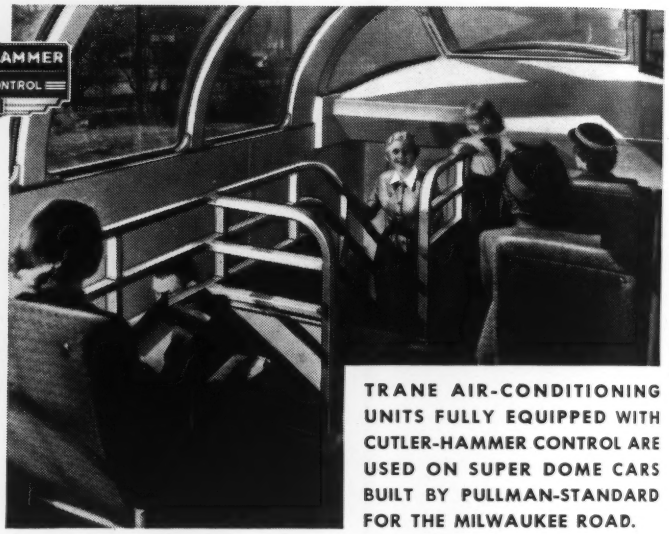
MOTOR CONTROL

C-H

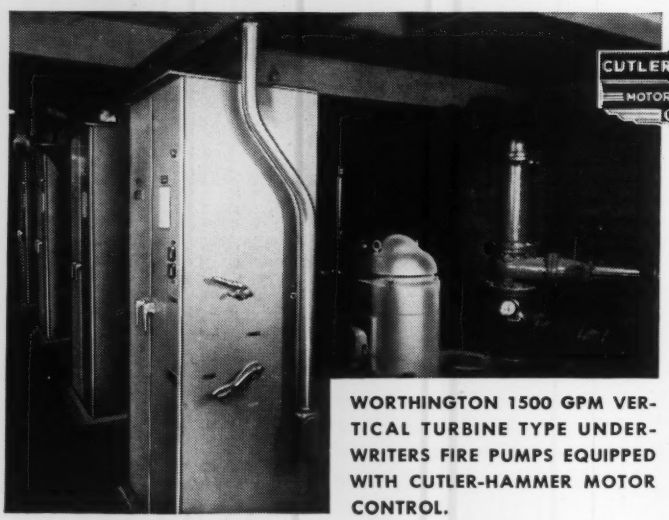
CHOICE OF THE LEADERS — THE MARK OF BETTER MACHINES



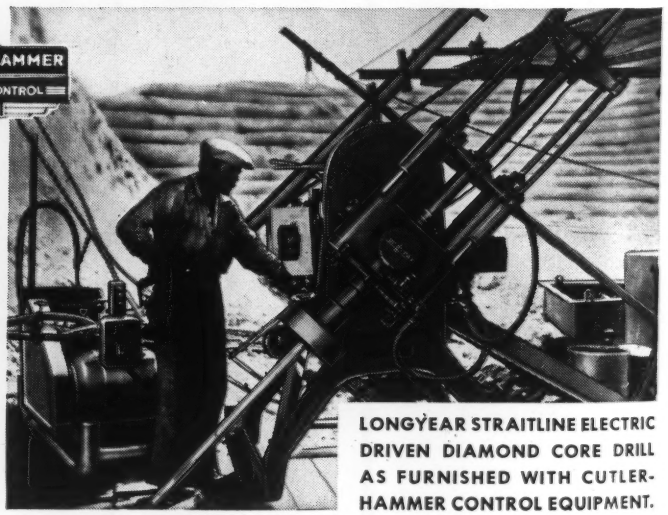
DENISON HIGH PRODUCTION MULTIPRESSES WITH CUTLER-HAMMER MOTOR CONTROL FURNISHED AS ORIGINAL MACHINE EQUIPMENT.



TRANE AIR-CONDITIONING UNITS FULLY EQUIPPED WITH CUTLER-HAMMER CONTROL ARE USED ON SUPER DOME CARS BUILT BY PULLMAN-STANDARD FOR THE MILWAUKEE ROAD.



WORTHINGTON 1500 GPM VERTICAL TURBINE TYPE UNDERWRITERS FIRE PUMPS EQUIPPED WITH CUTLER-HAMMER MOTOR CONTROL.



LONGYEAR STRAITLINE ELECTRIC DRIVEN DIAMOND CORE DRILL AS FURNISHED WITH CUTLER-HAMMER CONTROL EQUIPMENT.

What Makes a Leader?

Success is never an accident. Names that are instantly recognized as leaders mark the companies and products that have won widespread confidence through superior performance . . . superior performance under direct competitive comparison. Volumes could be written on the value leaders place on the trust granted their names, on the jealous care with which they guard it in everything they do. The point seems so clear that it requires nothing more than mere mention. Likewise, doesn't the simple fact that Cutler-Hammer Motor Control is found so frequently to be the choice of the leaders tell more about its performance . . . its leadership . . . than pages of glowing phrases? You will also find it pays to insist on Cutler-Hammer Motor Control. CUTLER-HAMMER, Inc., 1310 St. Paul Avenue, Milwaukee 1, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto.

THE PROFESSIONAL JOURNAL FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

APRIL 1954
Vol. 26—No. 4

EDITORIAL STAFF

COLIN CARMICHAEL, *Editor*
BENJAMIN L. HUMMEL, *Associate Editor*
ROBERT L. STEDFELD, *Associate Editor*
LEO F. SPECTOR, *Associate Editor*
KEITH A. CARLSON, *Assistant Editor*
ROBERT C. RODGERS, *Assistant Editor*
JOHN B. HOLT, *Assistant Editor*
LAURENCE D. SHERGALIS, *Assistant Editor*
JANE H. SMITH, *Assistant Editor*
FRANK H. BURGESS, *Art Editor*
ROGER W. BOLZ, *Contributing Editor*

New York ..... B. K. PRICE
L. E. BROWNE, SAMUEL W. BAKER
Detroit ..... FLOYD G. LAWRENCE
Chicago ..... ERLE F. ROSS
Pittsburgh ..... ROBERT M. LOVE
Washington ..... E. C. KREUTZBERG
London ..... VINCENT DELPORT

REGULAR DEPARTMENTS

Over the Board 4
Index 7
Topics 104
Engineering News Roundup ... 199
Meetings and Expositions 220
Helpful Literature 223
New Parts and Materials 228
Engineering Dept. Equipment .. 278
The Engineer's Library 293
Men of Machines 357
Stress Relief 372
Noteworthy Patents 378
New Machines 386

USE POSTAGE-FREE CARDS FOR:

INFORMATION
on products advertised 37

EXTRA COPIES
of editorial articles 207

ADDITIONAL DATA
on new products and methods . 223

Confusing or Convincing? ..... *Editorial* 111
Clarity of communication can help dispel the aura of mystery surrounding the engineering profession

Management of Drafting ..... *By Donald H. Rogers* 112
What can be done to improve efficiency and adequacy of drafting operations?

Scanning the Field for Ideas 123
Segmental lever design—adjustable flow rate—overload torque protection—optical data translation—centrifugal slip clutch—built-in flow diagrams—impact fastening

Pilot Lights 129
Selection and application of assemblies for specific indication uses

Jewel Bearing Systems ..... *By A. C. Lawson* 132
Considerations in designing bearings for instruments and miniaturized devices

Accuracy of Form ..... *By Allan H. Candee* 139
Specifying tolerances on form, direction and position for machine parts

Panel Latches 142
Design Details—Typical fastening methods for demountable assemblies

◆ ◆ ◆

Design Manual on Adhesives 143
A fundamental reference work summarizing current design practices and recommendations in selection and use of adhesives

◆ ◆ ◆

Compression Spring Design ..... *By Frank A. Votta Jr.* 175
A method for finding the best design when spring gradient is not fixed

Small Die Castings 181
Production and Design—Basic recommendations to assure suitable design

Stress Analysis in Design ..... *By J. B. Hartman and R. E. Benner* 186
Part 2—Factors that limit theoretical methods of stress prediction

Contemporary Design

Portable tape recorder 138
Tire cord tester 138
Inverted vertical press 180
Laboratory balance 184
Recorder reproducer 196

Design Abstracts

Evaluating gear performance .. 302
Magnesium surface finishes ... 306
Magnetic amplifiers 308
Developing new products 322
Sealing elements for rockets . 333
Relay selection 341
Minimizing fretting corrosion . 348

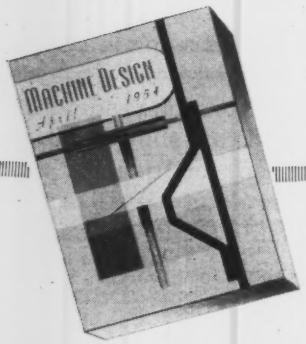
Over the Board

Introducing a New Editor

Latest addition to our staff is Laurence D. Shergalis, new assistant editor, whose picture appears on Page 357. Larry comes to us from the Hickok Electrical Instrument Co., where he was an electronic project engineer and also did patent and copyright work. He has held engineering positions with Brush Development Co., and Cleveland Electric Illuminating Co., and during the war served at the Ballistic Research laboratory at Aberdeen Proving Ground. A graduate of Case Institute of Technology (B.S. in E.E.), Larry also has a law degree from Cleveland-Marshall Law School, is a registered professional engineer (Ohio) and holds membership in the AIEE and the Cleveland Engineering Society. His hobbies include photography and repairing TV sets.

This Month's Cover

Inasmuch as the pastepot and shears are symbols of the editorial profession, the subject of adhesives is close to our hearts. But the joining methods discussed in the comprehensive "Design Manual on Adhesives" beginning on Page 143 are a far cry from the familiar paste, glue and mucilage of a typical office. Representing the fruit of extensive research and development by many concerns over a period of years, modern adhesives open up for the design engineer new and unusual opportunities for improved designs. To show adhesives on our front cover posed a problem to artist George Farnsworth, inasmuch as an adhesive in service is never visible. He has therefore done some exaggerating, as well as arranging a few colorful pieces of material held by adhesives in a pleasing design.



A Fabulous Achievement

In our preoccupation with the engineering marvels of our own time we tend to forget those of bygone days. A century ago two brilliant engineers, Isambard Kingdom Brunel and John Scott Russell, collaborated in the design and construction of the *Great Eastern,* a steamship five times the size of the biggest vessel then afloat. With only the crudest materials and production equipment, and with little store of engineering knowledge, these men by sheer ingenuity and courage created a design which even from today's perspective commands admiration. For a lively account of the adventures and misadventures of the ship and the men who built, operated and repaired her, we recommend James Dugan's *The Great Iron Ship,* recently published by Harper and Bros. With their meager resources, could you have done as well as Brunel and Russell?

A Double Package Next Month

Next month will see MACHINE DESIGN in two parts—a regular issue which will include a section on materials for special service, and a directory of materials. The directory is a revival of a feature which appeared as part of each October issue for seventeen years through 1950. The new edition will be more complete than in previous years, and is being entirely rewritten from new data.

MACHINE DESIGN

Penton Building, Cleveland 13, Ohio
Main 1-8260

BUSINESS STAFF

ROBERT L. HARTFORD
Business Manager

Advertising

New York 17 .....60 East 42nd St.
Russell H. Smith, Alan C. Bugbee
James A. Stangarone
Murray Hill 2-2581

Cleveland 13.....Penton Building
Harold B. Veith, Jack W. Walton
Main 1-8260

Chicago, Ill.....520 North Michigan Ave.
Howard H. Dreyer, Robert Z. Chew
Whitehall 4-1234

Los Angeles 48....6262 Commodore Sloat Drive
F. J. Fuller
Webster 1-6865

San Francisco 4.....57 Post Street
F. J. Fuller, Rober W. Walker Co.
Sutter 1-5568

Griffin, Ga..... 331 South Twelth St.
Fred J. Allen
Griffin 7854

London, S.W.1.....2 Caxton St., Westminster

Mary L. Callahan
Advertising Service Manager

Richard J. Strnad
Production Manager

Betty Root, *Staff Assistant*

Research & Promotion

Richard A. Templeton, *Research Manager*
George J. Auner, *Statistician*
Virginia R. Homad, *Staff Assistant*

Circulation

Jack C. Gernhard, *Manager*
Pauline J. Herndon, Josephine Kozak
Betty Lou Sadlowski
Amy Lombardo, *Directory & List Dept.*

Published by
THE PENTON PUBLISHING COMPANY
G. O. HAYS.....*President and Treasurer*
E. L. SHANER.....*Chairman*
R. C. JAENKE.....*Vice Pres., Director of Adv.*
F. G. STEINEBACH.....*Vice Pres. and Secretary*
J. P. LIPKA.....*Asst. Secy. and Asst. Treas.*

Also publisher of
Steel • Foundry • New Equipment Digest

Published on the seventh of each month. Subscription in the United States, possessions, and Canada: One year $10. Single copies, $1.00. Other countries one year, $20. Copyright 1954 by The Penton Publishing Company. Acceptance under Section 34.64 P. L. and R. authorized.

BPA NBP

INDEX

Advertising and editorial content itemized for convenience when studying specific design problems

A

Accumulators, hydraulic, Edit. 230, Adv. 28
Adhesives design manual, Edit. 143; Adv. 100
Aluminum and alloys, Edit. 218, 273; Adv. 12, 40, 61, 207, 257
Amplifiers, magnetic, Adv. 403
  magnetic, characteristics of, Edit. 308

B

Balance, cam operated, Edit. 184
Bearings, ball, Edit. 260; Adv. 11, 225, 228, 270, 323, 366
  jewel, designing with, Edit. 132
  miniature, improve tire cord tester, Edit. 138
  needle, Adv. 203, 243, 404
  rod-end, Adv. 64
  roller, Adv. 84, 203, 225, 233, 243, 353, 354, back cover
  sleeve, Adv. 35, 57, 201, 270, 272, 276, 348
Bellows, Adv. 103
Belts, conveyor, Adv. 290, 359
  timing, Adv. 326
  transmission, Adv. 75, 92, 272, 339. 397
Bender, tube, Edit. 388
Bimetals, Adv. 284
Books, Edit. 293; Adv. 308, 412, 420, 424
Brakes, Edit. 262; Adv. 45, 58, 296, 335
  fluid, like fluid coupling, Edit. 122
Brushes, cleaning, Adv. 340
  commutator, Adv. 43, 300, 348
Brush holders, Adv. 378, 421
Burring machine, Edit. 390

C

Cam operated balance, Edit. 184
Castings, centrifugal, Adv. 312, 338
  die, Edit. 181, 216; Adv. 90, 411, 419
  investment, Adv. 263, 282, 369, 396
  iron, Adv. 312, 401
  light alloy, Adv. 66, 328
  steel, Adv. 250, 401
Ceramics, Adv. 372
Chains, conveyor, Adv. 48, 271
  transmission, Adv. 48, 63, 271, 277, 331, 387, 425
Chucks, Adv. 435
Classified ads, Adv. 432
Clutches, Edit. 125, 126, 262; Adv. 45, 58, 228, 242, 301, 335, 347, 428
  magnetic, protects instrument drives, Edit. 384
Clutch facings, Adv. 83
Coatings, protective, Edit. 229, 242; Adv. 254, 437
Coils, electric, Adv. 427
Collector rings, Adv. 380, 429
Communication equipment, Edit. 208
Commutators, Adv. 378
Compression spring design, Edit. 175
Compressors, Adv. 22
Computer components, Adv. 209, 346
Computers, Edit. 218
Connectors, duct, Edit. 230
  electric, Edit. 266; Adv. 346, 424
Contactors, Adv. 291
Contacts, Adv. 43, 348
Control systems, electric, Adv. inside front cover, 309, 356, 431
Contest, Edit. 208, 212; Adv. 94
Controls, electric, Edit. 270; Adv. 342
  cable, Adv. 422, 430
  hydraulic, Adv. 307
Copper and alloys, Edit. 204; Adv. 35, 107, 324, 341
Corrosion, fretting, minimizing, Edit. 348
Counters, Adv. 317, 334, 431
Couplings, shaft, Edit. 256; Adv. 23, 350, 370, 386
Cutter, metal, Edit. 390
Cylinders, hydraulic, Edit. 234; Adv. 14, 95, 102, 315, 360, 374, 420, 424
  pneumatic, Edit. 234; Adv. 14, 95, 360, 374, 420

D, E

Data processor, electronic, Edit. 125
Dashpot, air-damp, Edit. 230
Diagrams, flow, indicate valve settings, Edit. 126
Diaphragms, Adv. 318
Design manual for adhesives, Edit. 143
Drafting equipment, Edit. 137, 282, 286, 290; Adv. 205, 381, 382, 398, 425, 426, 427
Drafting management, Edit. 112, 137
Drilling, Edit. 388, 390, 392
Drive mechanism, constant linear motion, Edit. 123
Drives, adjustable speed, Edit. 229, 249; Adv. 79, inside back cover
  roller gear, Adv. 360
Engines, Adv. 237, 433

F

Facilities, general, Adv. 16, 312, 348, 361
Fasteners, blind, Adv. 101
  bolts, nuts, screws, Edit. 244, 254; Adv. 24, 101, 215, 221, 222, 268, 311, 377, 385, 402, 408, 421, 424, 426, 432
  insert, Adv. 101, 260, 320
  locking, Adv. 215, 228, 429, 430
  pin, Adv. 297, 390
  retaining rings, Edit. 266, Adv. 375, 423
  rivet, Adv. 424
Fastening method eliminates fasteners, Edit. 127
Felt, Adv. 278, 330
Filters, Adv. 407
Finishes, protective, Adv. 254
  protective, for magnesium, Edit. 306
Fittings, pipe, tube and hose, Edit. 230; Adv. 231, 344
Forging, Adv. 365
  impact, Adv. 261
Form tolerances, specifying, Edit. 139
Forming, Adv. 76, 361
Fretting corrosion, minimizing, Edit. 348
Friction materials, Adv. 359

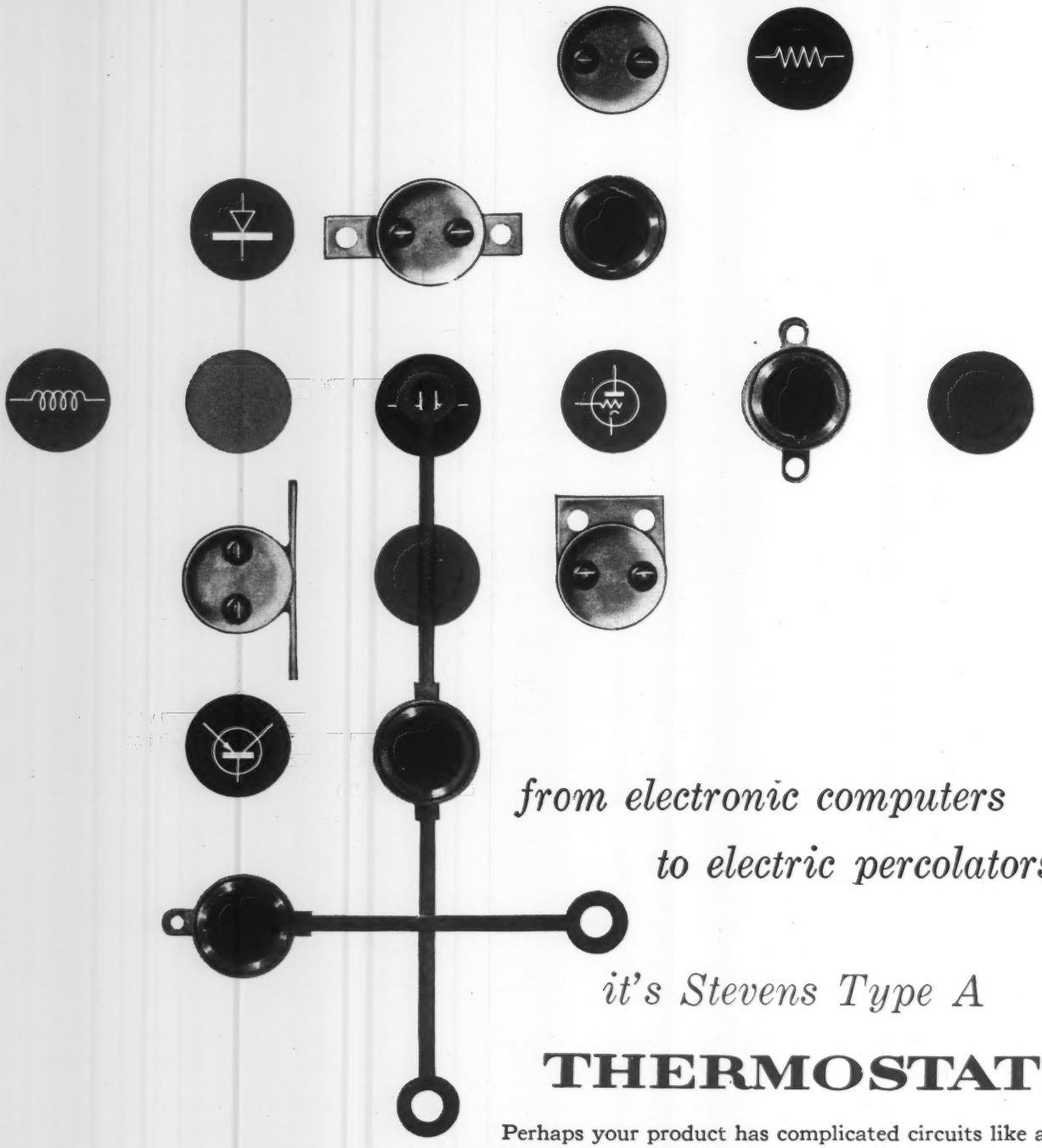
G

Gaskets, Adv. 19, 259, 293, 358
Gas turbine for helicopters, Edit. 202
Gears, Edit. 234; Adv. 31, 255, 264, 305, 343, 357, 365, 392, 422, 429
  performance of, evaluating, Edit. 302
Grinding, Edit. 388, 392; Adv. 406

H

Handles, Edit. 252; Adv. 421
Heaters, Adv. 47, 431
Heat exchangers, Edit. 238; Adv. 78, 364, 373
Heat resistant alloys, Adv. 273
Heating and ventilating machines, Edit. 386

(*Concluded on Page* 10)



from electronic computers

to electric percolators . . .

it's Stevens Type A

THERMOSTATS

Perhaps your product has complicated circuits like a computer. Or a simple one like a percolator. In either case if it requires quick, snap-action heat control, better look into the Type A* thermostat, a newcomer to the Stemco line. For it features rapid, complete heat transfer and an electrically independent bimetal disc that eliminates false cycling. And it's smaller in diameter than a dime.

But perhaps best of all, Type A thermostats are *in production* with a wide variety of terminal arrangements and mountings, either in semi-enclosed or hermetically sealed styles. This means there's every chance your special temperature control requirements can be met by a standard production-line Stemco thermostat. *Big cost and assembly savings result.*

So let's match our product against your product's needs. It'll probably save your time, temper and money. A card will bring our representative on the double.

A-9[illegible]

Stevens also makes thermostats used in leading makes of: Roasters • Fry Kettles • Vaporizers • Flat Irons • Butter Warmers • Refrigerators • Water Tanks • Waffle Irons • Percolators • Steam Irons • Sterilizers • Rectifier Fans • Electronic and Avionic Devices

STEMCO

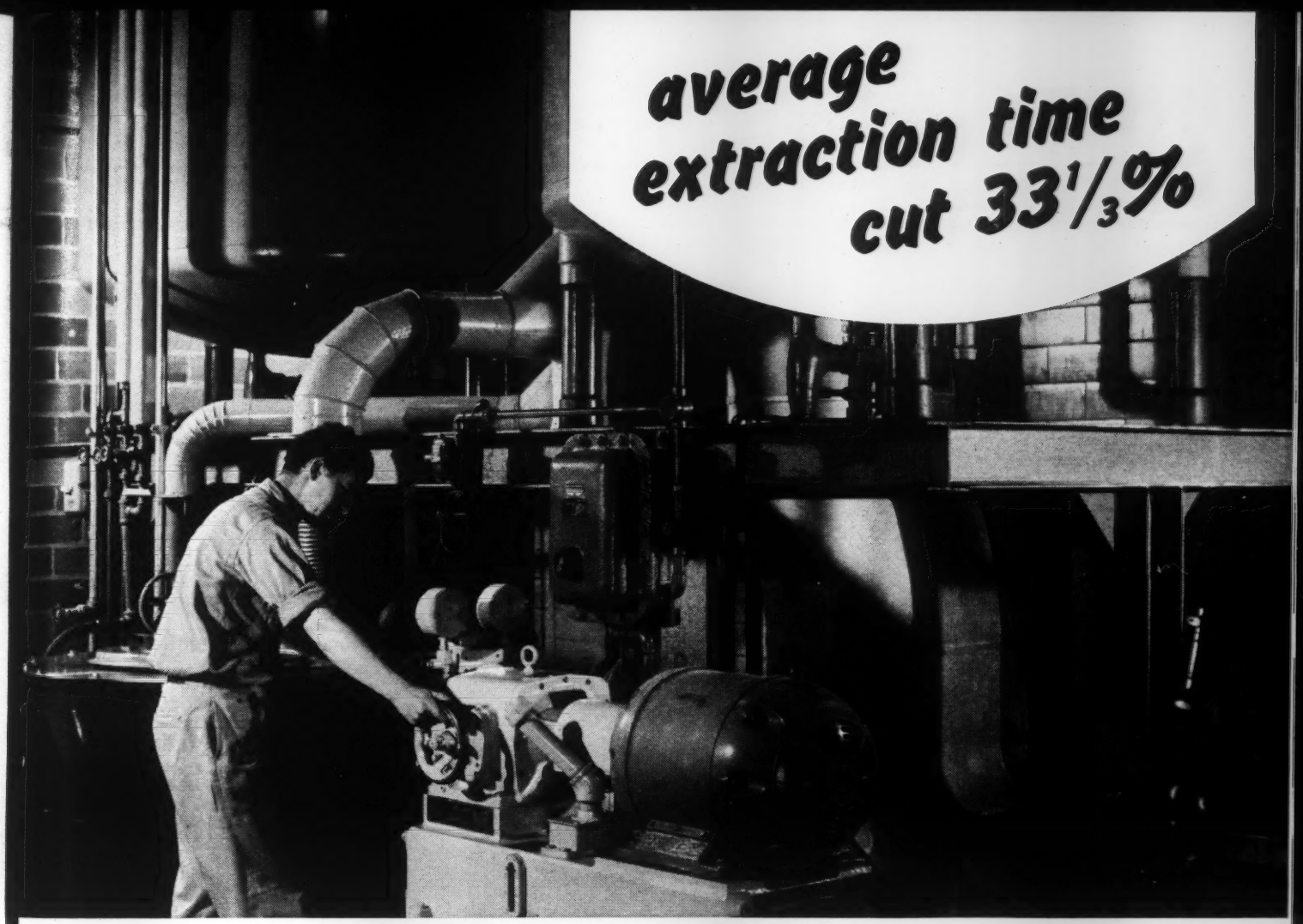
THERMOSTATS

designed and manufactured by

STEVENS manufacturing company, inc.

Mansfield, Ohio

*Patent Pending



Once more the ANY-SPEED Oilgear Drive betters machine performance "painlessly"

Many times in our experience the performance of an already highly efficient machine has been bettered without redesign, solely by changing the drive. One case out of many *varied* cases, is the Tolhurst Centrifugal pictured above, located in a great pharmaceutical house. This centrifugal was originally equipped with a two-speed electric motor drive. However the chemicals it is called upon to handle have widely varying crystal packing characteristics. Some of these crystals packed so densely at the speed available, extraction was inhibited, extraction time far out of balance and crystal removal difficult.

A change was made to an *"ANY-SPEED"* Oilgear Fluid Power Drive. Now the operator is able to shade the speed of the centrifuge experimentally—*and easily discover* the *best* speed for each batch of crystals.

As a result, extracting that used to take from 6 to 9 hours was cut to 4 to 6 hours. The extremely slow speed also available made unloading a great deal easier. This user now has several other Oilgear drives including one on a laboratory centrifuge.

There is very often a direct efficiency coefficient between machine operating speed and the type of work being handled. And we can cite many widely varying instances where equally dramatic and profitable gains resulted at once from a simple change to *"ANY-SPEED"* Oilgear Fluid Power Drives. If you want some interesting factual data on Oilgear's steplessly variable speed drives, their outstanding responsiveness to control impulses, their smooth acceleration and deceleration, talk to an Oilgear Engineering Representative. His mature and sound engineering recommendations may profit you greatly. THE OILGEAR COMPANY, 1568 W. Pierce St., Milwaukee 4, Wisconsin.

OILGEAR

OILGEAR

INDEX

(*Concluded from Page 7*)

Hose, metallic, Adv. 34, 97, 321
non-metallic, Adv. 228, 245, 367
Hydraulic equipment (see also specific type)

I

Indexing mechanism, Edit. 240; Adv. 360
Induction heating, Adv. 93
Inspection, Adv. 433
Insulation, Edit. 212; Adv. 413, 416

J, L

Jewel bearings, designing with, Edit. 132
Latches, Edit. 142
Lights, pilot, selecting and applying, Edit. 128
Lubricants, Adv. 364
Lubrication equipment, Adv. 89, 235, 265, 388, 407

M

Machining facilities, Adv. 16
Magnesium and alloys, Adv. 295
finishes for, Edit. 306
Magnetic amplifiers, characteristics of, Edit. 308
Management, engineering, Edit. 112, 137, 372
Materials handling, Edit. 386
Materials, Edit. 249; Adv. 412
Mechanism, drive, constant linear motion, Edit. 123
Meetings and expositions, Edit. 199, 204, 208, 220; Adv. 345, 352
Metals (see specific type)
Motors, electric:
brakemotors, Adv. 296
fractional and integral hp, Edit. 212, 234; Adv. 13, 17, 65, 87, 91, 269, 274, 296, 351, 356, 362, 379, 389, 391, 395, 414
gearmotors, Edit. 232, 273; Adv. 82, 296, 371, 426
repair service, Adv. 71
subfractional, Edit. 254; Adv. 389
timing, Adv. 108, 419
Motors, hydraulic, Adv. 9, 102, 283, 306
hydraulic, ball piston, Edit. 378
Motors, pneumatic, Adv. 22
Mountings, vibration and shock, Adv. 322, 405

N

Nameplates, Adv. 419
New products, developing from prior patents, Edit. 322
Nickel and alloys, Adv. 423
Nylon, bonding to rubber, Edit. 214

P

Packings, Adv. 54, 259, 358, 376, 394, 415, 428
Patents, prior, developing new products from, Edit. 332
Pilot lights, selecting and applying, Edit. 128
Pipe, Adv. 228, 231
Plastics, Edit. 200; Adv. 39, 41, 109, 244, 289, 352
Plastics molding, Adv. 6, 355
Pneumatic equipment (see specific type)
Portable tools, Edit. 392
Potentiometers, Edit. 236; Adv. 428
Powder metallurgy, Adv. 219, 238, 281, 359
Press brake, Edit. 388
Pulleys (see also Sheaves)
Pumps, Edit. 242; Adv. 22, 44, 336, 370, 384, 409, 422, 433
hydraulic, Adv. 72, 95, 102, 239, 283, 294, 296, 306, 314, 399, 426
hydraulic, ball piston, Edit. 378
pneumatic, Adv. 22
Press, inverted vertical, Edit. 180
Pressure transmitter, Edit. 246

R

Recorder-reproducer records for 24 hours, Edit. 196
Rectifiers, Edit. 278; Adv. 236
Reducers, speed, Adv. 77, 96, 213, 267, 352, 363, 392, 426
Reels, cable and hose, Adv. 429
Regulators, pressure, Adv. 265
Regulators, flow, Adv. 368
Relays, Edit. 230, 232, 264, 276; Adv. 85, 256, 291, 325, 329
selecting, design factors in, Edit. 341
Research & Development, Edit. 200, 278, 280, 282, 284, 286, 288, 290; Adv. 209, 249, 366
Resistors, Adv. 55
Rings, seat, Adv. 229
Rubber, Edit. 256; Adv. 25, 400
bonding to nylon, Edit. 214
Rubber molding, Adv. 286, 349

S

Screws, power, Adv. 319
Seals, Adv. 50, 293, 410, 415
mechanical, Edit. 381; Adv. 2, 50, 211, 259, 262, 376, 410
piston, Edit. 234
Seals, in rockets, Edit. 333
Sealing tape, felt, Edit. 264
Servos, Edit. 238; Adv. 26
Shafting, Adv. 298
Shafts, flexible, Adv. 86, 332
Shapes, special, Adv. 76
Sheaves, Edit. 259; Adv. 272, 397
Shims, Adv. 240
Sintered metal parts, Adv. 43
Small die castings, designing, Edit. 181
Small precision parts, Adv. 70
Spacers, Edit. 234
Springs, Edit. 175; Adv. 20, 73, 422, 430
vibration damper for, Edit. 378
Saw, metal, Edit. 390
Sprockets, Adv. 75, 271, 425
Stamping, Adv. 393
press, Edit. 390
Starters, motor, Adv. 232
Steel, Adv. 30, 52, 227, 253, 266, 298
Steel, stainless, Edit. 208; Adv. 52, 285
Stress analysis, Edit. 186
Switches, Edit. 240, 244, 259, 270; Adv. 68, 98, 228, 241, 287, 316, 329, 342, 357, 368, 420
Systems, hydraulic, Adv. 28, 60, 102, 283, 399, 430
pneumatic, Adv. 28, 430

T

Tape recorder, battery operated, Edit. 138
Testing and inspection, Edit. 210, 392; Adv. 337, 366
Thermostats, Edit. 229; Adv. 8, 27, 88, 428, 431
Timers, Edit. 252; Adv. 67, 252, 334, 368, 419
Titanium, Adv. 273
Tolerances, form, specifying, Edit. 139
Transformers, Adv. 354
Transmissions, variable speed, Adv. 26, 299, 344, 386
Tubing, Adv. 42, 46, 105, 438
bender, Edit. 388

U, V

Universal joints, Adv. 248, 386
Valves, Edit. 229, 260, 268; Adv. 217, 231, 246, 279, 280, 288, 428
hydraulic, Edit. 232, 381; Adv. 95, 102, 241, 283, 306, 315, 372, 420, 425
hydraulic, motor-driven, Edit. 124
pneumatic, Adv. 1, 53, 80, 95, 241, 372, 420, 423, 425
Voltmeter, vacuum-tube, Edit. 232

W

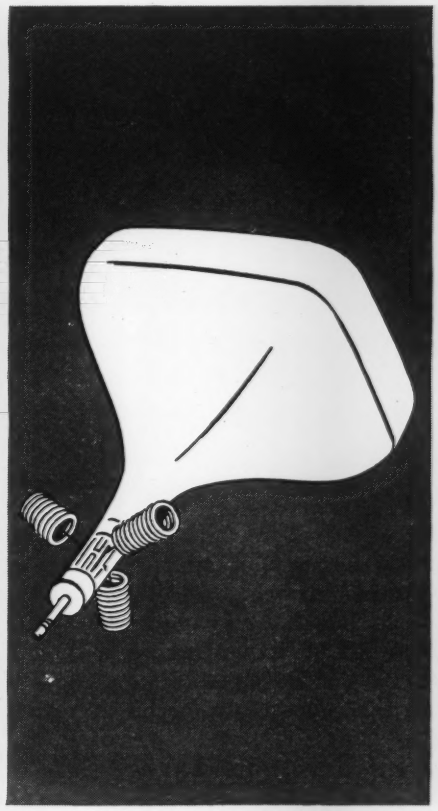
Welding, Adv. 18, 313
Weldments, Adv. 51, 247, 342
Wire and wire products, Adv. 20, 290, 422, 430

MACHINE DESIGN is indexed in Industrial Arts and Engineering Index Service, both available in libraries, generally

IDEAS that start in a BELLOWS

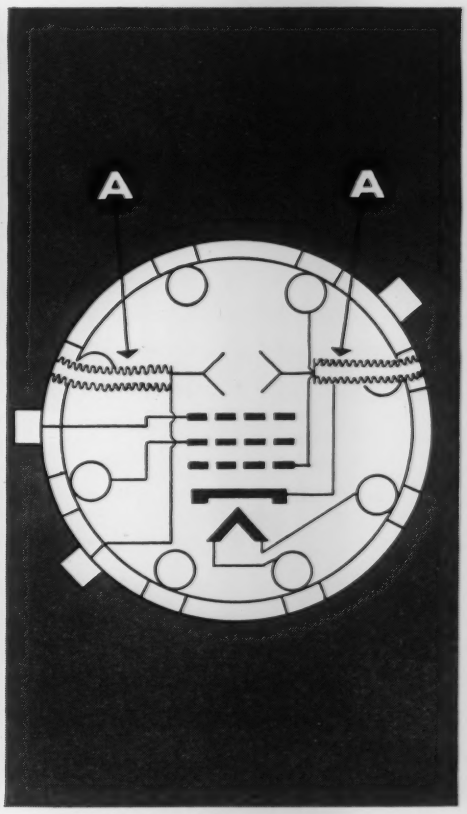
WHY ADJUST A COLOR TV TUBE FROM WITHIN?

If you can physically move the deflection plates within a TV tube without breaking the hermetic seal, you will get much finer tuning, clearer images. But how can this be done?



BELLOWS GIVES PROPER SEAL

To make *any* physical adjustment within a vacuum, you need a seal that is both leakproof and flexible. This is what you get when you use a Clifford Bellows. For instance —



HERE'S HOW IT CAN BE DONE

In the diagram, you can see how a Clifford Bellows (A) can be inserted in the deflection plate circuit. Plates can be adjusted within the TV tube without affecting the vacuum.

Have you ever worked with Bellows?

Although bellows aren't always featured in engineering courses, they have proved a welcome solution to many engineering problems.

The color TV tube application outlined above is but one of many ways in which these leakproof, flexible assemblies can prove useful. For instance, in the electronic field, Clifford Hydron Bellows change the frequency inside magnetron tubes, make adjustments inside hermetically-sealed instruments, move variable plates inside vacuum capacitors. They also act as expansion chambers in mercury-filled wave guides, oil-filled transformers and other electronic and electrical equipment.

Clifford Hydron Bellows permit extension, retraction and 360° rotations with 100% metallic seal.

CLIFFORD MANUFACTURING COMPANY, Grove Street, Waltham 54, Massachusetts. *Div. of Standard-Thomson Corporation.* Sales offices in New York; Detroit; Chicago; Los Angeles; Waltham, Massachusetts.

CLIFFORD MANUFACTURING COMPANY
124 Grove Street, Waltham 54, Massachusetts

Gentlemen:

Please send me information on bellows application for vacuum tube adjustments. Also for:
☐ Transmitting motion between mediums ☐ Controlling and indicating temperature ☐ Sealing rotary shafts or packless valves ☐ Transmitting motion hydraulically to remote points ☐ Providing for thermal expansion ☐ Providing shock mounting or vibration dampening ☐ Differential pressure maintenance

Name.....

Company.....

No. and Street.....

City.....Zone.....State.....

MACHINE DESIGN

Topics ...IN ENGINEERING AND RESEARCH

New Engine Muffler Makes Sounds Vanish

By boosting exhaust sound frequency to a higher pitch than the normal hearing range, engineers at Reo Motors Inc. say they have licked most of the muffling problem for small gasoline engines. Utilizing the familiar "silent" dog whistle principle, the new muffler produces the super high-pitch tone by passing exhaust gases through orifices which increase velocity, cut down pressure, and thus change sound-wave frequency. About 50 per cent of the sound waves "disappear" and low back pressure—important in low-horsepower engines—is not appreciably sacrificed. Final sound level is 75 decibels.

Interlingua—a New Technical Language

Blended of English, French, Italian, Spanish, Portuguese and a small amount of German, a new technical language called Interlingua is the latest attempt to bridge the language barrier. In development since 1923, Interlingua has been given impetus in this country by publication of a 27,000-word Interlingua-English dictionary several years ago and the new Interlingua a Prime Vista (Interlingua at First Glance) this year. The dictionary includes 17,000 technical terms.

Slip-Ring "Noise" Caused by Jumping Bushes

Minute irregularities in slip-rings, which cause complete separation of the brush and ring at high speeds, are the major causes of electrical "noise" in low-current signal circuits, according to a study by Armour Research Foundation. Electrical noise generated by the sliding contact has been one of the major difficulties in obtaining consistent results with strain gages. A brush system designed to minimize the effect has been developed and is now being evaluated.

Higher-Strength Titanium Parts Possible by Heat Treatment

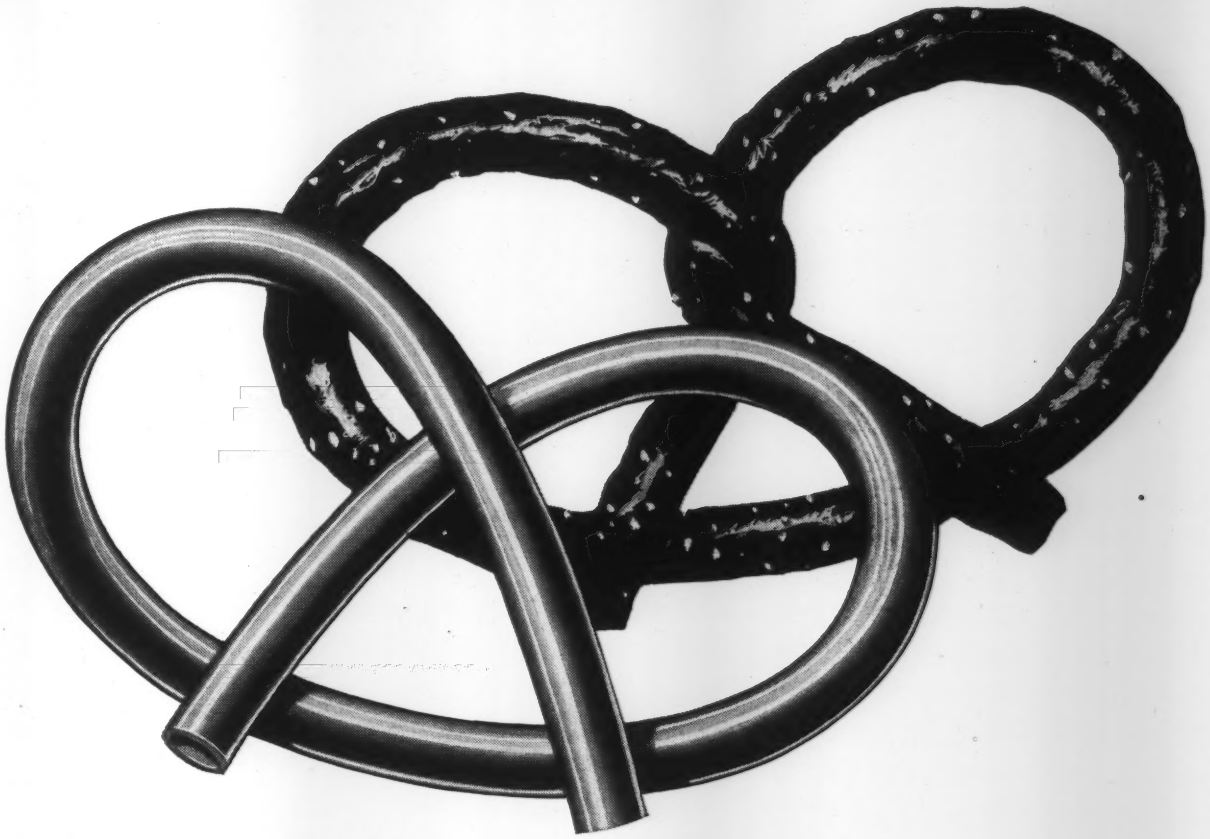
Among the methods of heat-treating titanium alloys to give outstanding tensile properties is a newly reported procedure that may permit treatment to high strength levels after machining or forming. According to a Battelle Memorial Institute study for the Air Force, experiments indicate that solution heat treatment of certain alloys at about 1300 F, machining or forming the part, then age-hardening the part to high strength, may be commercially possible. These alloys may be stable for extended periods at operating temperatures up to 600 F.

Copper Successfully Electroplated on Titanium

An etching process developed by Armour Research Foundation for the Watertown Arsenal permits copper deposits to be applied on titanium in an adherent form. Present work is directed toward production of a true metal-to-metal bond.

Acoustic Method Tests Nonmetallic Solids

A new ultrasonic technique can be used for nondestructive testing of rubber, graphite, plastics, concrete and wood. Producing high-contrast records of flaws, the process is said to be more sensitive than X-ray photo-



what's a pretzel got to do with tubing?

Just this—like a pretzel baker, OSTUCO is a specialist in bending, too! But it is only one of OSTUCO's many versatile facilities for manufacturing, fabricating, and forging. You'll always find OSTUCO a dependable *single source* for both carbon and alloy steel tubing, and its quality is strictly controlled from raw materials right on through to prompt shipment to you. If you're presently using tubing or if you're considering its use in your product, write for our newest catalog, "OSTUCO TUBING." Better yet, send us your blueprints for a quotation. OSTUCO's engineering and design staffs are always available to work with you on problems concerning tubing.

By the way, did you know that Shelby, Ohio was the birth place of the seamless steel tube industry in America?

OSTUCO TUBING

OSTUCO SHELBY, OHIO

SEAMLESS AND ELECTRIC WELDED STEEL TUBING —Fabricating and Forging

OHIO SEAMLESS TUBE DIVISION
of Copperweld Steel Company • **SHELBY, OHIO**
Birthplace of the Seamless Steel Tube Industry in America

SALES OFFICES: BEVERLY HILLS • BIRMINGHAM • CHARLOTTE CHICAGO • CLEVELAND • DAYTON • DETROIT • HOUSTON LOUISVILLE • MOLINE • NEW YORK • PHILADELPHIA PITTSBURGH • SALT LAKE CITY • ST. PAUL • SEATTLE SYRACUSE • TULSA • WICHITA

CANADA, RAILWAY & POWER CORP., LTD.

EXPORT: COPPERWELD STEEL INTERNATIONAL COMPANY
117 Liberty Street, New York 6, New York

graphs, gives immediately available test results and is free from high-voltage and radiation hazards. With the method developed by Reed Research Inc., a pair of barium titanate transducers transmit and receive acoustic energy at 383 kilocycles per second along radii of a cylindrical test piece rotated about its longitudinal axis at 100 rpm. The transducers simultaneously traverse the cylinder at 0.1-inch per cylinder revolution, producing a helical scan. Output is fed to a tungsten stylus in contact with electrosensitive paper, leaving a dot trace whose intensity corresponds to energy level. More complicated shapes can be scanned by comparing with the record of a flawless piece.

Catalyst Cap Replaces Lost Battery Water

Batteries are serviced almost automatically and can go seven times longer before additional water is needed with catalyst-filled Hydrocaps, according to the manufacturer, Industrial Research Inc. The Hydrocap replaces the usual cell cap in automobile or industrial batteries and catches oxygen and hydrogen released when the battery is overcharged in driving. A palladium-coated catalyst reunites the gases and returns the resulting water to the battery cells. As the droplets trickle back, they also absorb escaping sulphuric acid fumes, eliminating a common cause of corrosion.

Measures High Electric Potential Between Earth and Atmosphere

A supersensitive electronic device designed to measure the high electric potential existing between the earth and ionosphere (layer of air just above the stratosphere) has been developed. A potential upward of 100,000 volts exists, previously measurable only by instruments carried on airplanes to 35,000 feet. Research to 100,000 feet will be possible with the new "aerial electrometer" developed by Minneapolis-Honeywell Regulator Co. to be carried aloft by plastic balloons. Data are also expected to be valuable in helping determine the source of a current of 1800 amperes which constantly flows toward the earth from upper regions.

Steel Industry Plays Cops and Robbers

Crook, arrests, charges, trial bar and similar terms are well-known to detective story fans—but they also have perfectly valid meanings in iron and steel terminology, as the American Iron and Steel Institute points out. A "crook" is a distortion sometimes produced in cooling castings; "arrests" are interruptions in certain steel processes; a "charge" is the term for raw materials put into a blast furnace; a "trial bar" is a sample bar selected at random for inspection; and "hanging" is what happens when raw materials stick to the sides of a blast furnace or hopper.

Nondestructive Thermocouple Comparator Sorts Out Mixed Metals

Operating on a thermocouple principle, a nondestructive metal comparator developed at General Motors can sort out mixed lots of metals with very similar alloy contents. Basic principle—that of a thermocouple loop—involves the use of the comparator probe tips where they touch the metal being tested as hot and cold junctions. When the probes and metal under test are different, a current flows, with voltage dependent on the metallic composition of the test piece. Mixed stocks of SAE 1112 and 1117 steel, differing only 0.05 per cent in carbon content, have been separated, and the instrument is even sensitive enough to detect chills in castings.

MACHINE DESIGN
APRIL 1954

Confusing or Convincing?

ONE OF THE hallmarks of a professional man, whether he be in law, medicine or engineering, is fluent use of the technical words and expressions peculiar to his work. To complicate things the lawyers and doctors have their Latin words and the engineers their Greek symbols.

However much these devices contribute to clarity of communication within the profession, to the layman they are so much jargon. When they are used in his presence he is likely to feel frustrated if not actually suspicious that someone is trying to impose on him. This is true whether it be a lawyer or doctor explaining to a client or patient why the fee is so high or an engineer explaining to management why a project is costing so much. In no case does the unfamiliar language enhance the profession or its practitioner.

Kettering puts it this way: "We need to tell our associates that we are not a special set of superintelligents different from other people, that we make just as many mistakes, maybe more, only we try to describe them in language that the management doesn't understand."

By using language intelligible to our hearers we can dispel the aura of mystery which surrounds ourselves and our work, and establish a reputation for forthright dealing. Ours is a young profession, not molded into a set pattern, and we as engineers have an opportunity to create a unique professional relationship with our public—our nonengineering associates and management people—founded on respect and on freedom from the suspicion that we ever try to confuse when we should be trying to convince.

Colin Carmichael

EDITOR

MANAGEMENT OF DRAFTING

By Donald H. Rogers
Chief Engineer
Blonder-Tongue Laboratories
Westfield, N. J.

DRAFTING, like the poor, is always with us. No company with appreciably diversified production can escape its many pains and pleasures.

There may be little need for drafting in a company making only one or two items—particularly so if these items are kept in continuous production and the whole process is handled from beginning to end in one plant. But if a company buys to specification, sells to specification, makes many items or makes complex items intermittently, then manufacture to specification is required and drafting is a necessity. It may be profitable to take a birds' eye view of how drafting impinges on all plant operations, where it costs money and where it can save money.

The direct costs of drafting are high. It costs several dollars per man hour to operate a crew of draftsmen, including space and supervision and a reasonable allowance for materials and reproduction service. "And what do we have to show for it? Drafting errors which cost us money in the tool room!" And the costs of designing, and the error rate, are still higher. These costs, however, can be monitored by good local supervision.

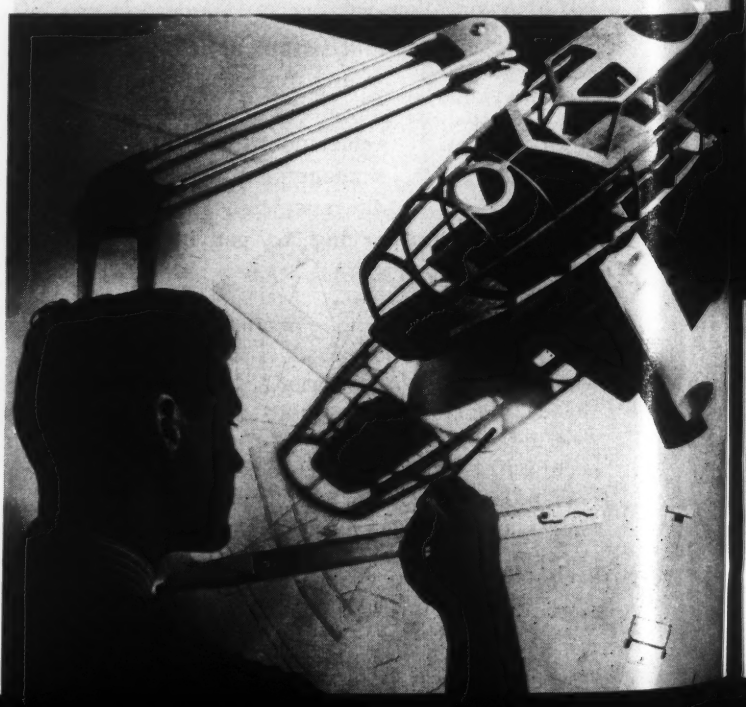
The relationship between the drafting room and the rest of the plant is a matter of paramount concern. Drafting cannot be cut off from the rest of the organization and delegated as a minor detail to the engineering department. Drawings go out to all departments, to purchasing, wage incentives, cost accounting, production control as well as to operating and inspection, and they may click along with simple, orderly dispatch or they may cut a wide swath of bewilderment and confusion. The drafting program must be adapted to the needs of the business.

Why Drafting At All?: Drafting is not an end in itself, except as an unfortunate local view within the drafting room. Drafting is a way of specifying. Drawings are specifications. They exist in such form because one picture is worth a thousand words. That is their whole reason for being. But why specify?

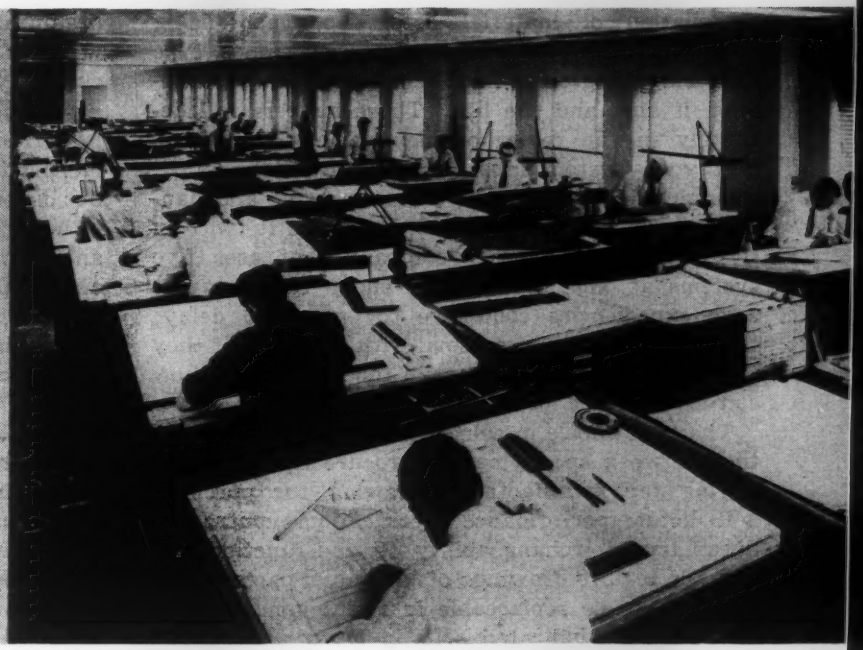
Drawings are a vehicle for storing and transmitting information which can be expressed most

". . . drawings are a vehicle for storing and transmitting information which can be expressed most economically and effectively with the aid of picures . . ."

Photo, courtesy Boeing Airplane Co.



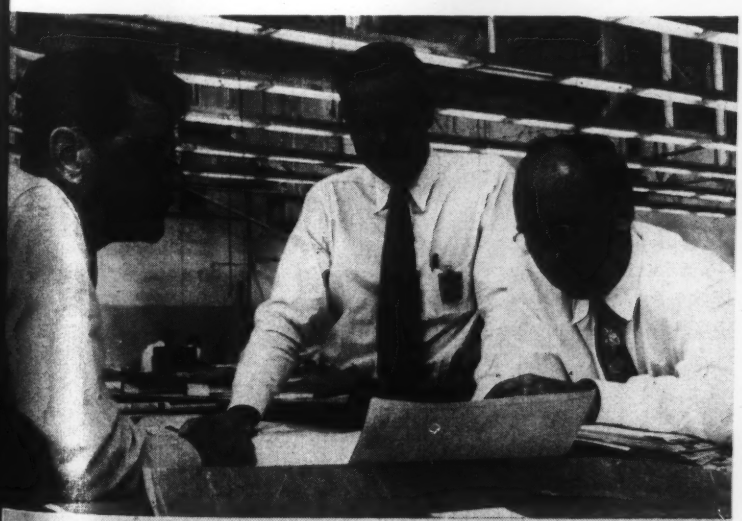
Influence of the drafting room reaches to all corners of a company. Efficiency and adequacy of drafting operations are tangible economic factors of importance. This article presents a clear-cut analysis of the problems to be considered, the questions to be asked, and the answers to be evaluated



Photo, courtesy Aluminum Co. of America

economically and effectively with the aid of pictures. No drawing is ever necessary. A person with a good command of English can describe a doorknob by using such terms as "oblate spheroid," "minor diameter," and "a radial hole ⅛-inch in diameter, located ¼-inch from the truncated cylindrical end," and he can describe an electron tube or a hypoid gear the same way. But drawings are economical and effective and convenient to use.

The purpose of drafting is communication. A drawing exists to communicate. If it can't be read, it might better not exist. If it leaves the cost accountant up in the air as to how many gears go in the box, it is not a good drawing. If it leaves the buyer up in the air on voltage ratings required, it is not a good drawing. If it leaves the production control department uncertain on whether to paint or plate, it is not a good drawing. Pictures may be pretty, but industry cannot afford art for art's sake. Neither can it afford to hold parts to 1/64-inch when 1/8-inch is good enough, or to 2 volts when 20 volts is close. Good drawings say what is necessary and then stop.



Photo, courtesy Douglas Aircraft Corp.

". . . costs of designing . . . can be monitored by good local supervision . . ."

It is usually desirable to distinguish between drafting for the product and drafting for facilities. Few companies can handle maintenance and replacement without some sort of drawings of their plant layout and fixtures, their tools and test equipment. On the other hand, few companies find it either necessary or possible to lavish the time and money on drawings of their facilities which they would find minimal for drawings of the product.

It is not necessary to discuss facilities drawings here, except to suggest that they be developed from the system used for the product by introducing shortcuts wherever practical. Such a method makes it easier for new people to learn the ropes when they start work. The rest of this discussion will refer only to drawings and drafting for the product.

Choosing a System: The first step is to weigh carefully the present and probable future needs of the business and to select a drafting system which is adequate for all forseeable requirements imposed by healthy expansion. A drafting system is more than light lines or heavy lines or third-angle projection. It is a body of decisions and agreements on product identities, part and drawing numbers,

compilation of material lists, departmentalizing of generations, presentation of subassemblies, type of wiring diagrams, handling of company standards, if any, and the like. These matters fall definitely in the realm of management.

A good system must be chosen at the start. Changing in midcareer is both expensive and dangerous. There is one company that did it twice in five years, and another company that uses five systems at once in the same shop. Not only are such expediencies conducive to error and delay; they also raise the very devil with morale. "If they don't know what they want in the front office, how can they expect me to give it to them?"

The first choice in selecting a drafting system is that between specifying for procurement and specifying for manufacture. Drawing for purchase will dictate performance specifications controlling durability, interchangeability, fit and function, but will not require drawings of individual parts unless they are to be replaceable in maintenance. Many parts can be indicated only in assembly with no part numbers assigned. In short, it is possible to get away with murder when purchasing a power transmission, a pneumatic actuator or an electronic control to the user's specifications. Even here, however, the purchasing department may find savings in time or price if a subcontractor does not have to make up his own drawings. It may be better to give him more detail than to have him redraw.

Drawings for manufacture usually take on some of the character of manufacturing process specifications. This is inevitable, since they must in some degree be arranged to correspond to plant organization. It is a matter of choice, however, whether to specify dimensions by referring to tools currently available and whether to generate subassemblies according to a particular foreman's preferred bench layout or to make the drawing an independent package describing the product without dependence on present manufacture. It depends on what the business needs, how much it is worth, and how much growth and change are likely. It also depends on how soon the product will be obsolete, if ever.

Drawings must be suited to the manufacturing process at least to such degree that work can flow through the plant with intelligent control, that interdepartmental records can be kept and transmitted readily, and that the piece-rate structure can be handled economically and without the kind of confusion leading to poor labor relations. Parts in the bin should have a name and number for the associated paper work, whether they are being stored or only transferred. It can be business suicide to use the cost of raw castings when preparing a bid covering machined ones because there is only one part number for them either way and the cost accounting department can't tell from their records which form the figures apply to.

In some companies paper work comes pretty close to being the tail that wags the dog, and everybody has too much of it. It pays to recognize this evil in setting up the system and thus, attempt to get the best of a bad bargain.

Typical Systems: One company has a very simple drafting system. They use a master parts list for each product, accompanied by a schematic

Table 1—Organization of Engineering Drawings

1. Provide a separate drawing of each part, as delivered to assembly or subassembly, with a number to identify it.
2. Provide separate drawings for raw castings and weldments which are bought or stored unfinished and then taken out for machining.
3. Provide a separate drawing for each subassembly which is assembled by machine shop rather than assembly shop methods, such as riveting, spinning, welding. Make each of these drawings complete with material list.
4. Provide a main assembly drawing with its associated material list. Let the material list be a drawing, but on a separate sheet so that it can be used by clerical departments for ordering and accounting purposes.
5. Provide no subassembly drawings for work done in the assembly shop.
6. Handle the necessary details of assembly information either by a series of sections and views and detail sketches on the main assembly drawing, or by the same views on separate information drawing sheets which carry no material lists but refer to the main material list for part identities.
7. If there is a large amount of assembly information, let the main material list indicate in which assembly views or on which auxiliary assembly information sheets each item is specified for assembly, and what the subtotal is for that application.

and by part drawings for those purchased parts which cannot be described in ten or fifteen words. There is no wiring diagram or assembly drawing; the shop uses samples and depends on the job knowledge which goes with continuous production. Company-made parts have no drawings if they can be defined by the dies and by profuse samples. A system of part numbers covers all purchased parts and it can be readily mastered because of its transparent simplicity, but it is totally unsuited to mechanical tabulating and will have to be swept out when the company grows to the point of introducing bookkeeping machinery. Few written testing specifications are used, but conscientious adjusting and retesting by a high-toned force maintain an exceptional quality level.

This company has quite a stake in continuity of production and in training of personnel, but the management is alive to the problem and is taking a calculated risk.

A second company prepares two complete sets of drawings of each product, the first when the design is completed and the second when it goes into production. Both sets are kept up to date, the one showing each change and improvement in design when it is approved by engineering and the other showing it only when it actually goes into the product, which may be a year later if tool and stock conditions occasion delay. The shop drawings include complete material lists and assembly information, generation by generation. Separate drawings and part numbers are assigned to each machined part and machine assembly, but the generations of final assembly and subassembly are all shown as assembly views and sections without part names or numbers. Tolerances and testing requirements are rigorous, covering even alloys of steel and dimensions of thread profiles. Nothing is left to chance or to unwritten shop practice.

The system is expensive in the immediate view but is economical for that business in the long run, since the company is practically immune to rotation of personnel in spite of handling many products on an intermittent basis and since they expect to stay in business for at least another fifty or hundred years.

A third company has made a neat compromise. One complete set of drawings is prepared of each product, including a material list at each level. Subassembly drawings are prepared to fit the flow of work in the shop, and performance specification drawings are made up for parts to be purchased. This involves a certain amount of advance collaboration between engineering and production, which is handled through weekly meetings. The company relies on shop practices for inside work, so far as these practices are uniform in the industry, but depend on published standards for outside work. Drawings often refer to ASA, SAE, and AISI publications.

However, this company has fallen into a morass in integrating the system into the paper work requirements of the business. In addition to the material list information which is nominally complete on drawings, the engineering department recompiles this data in two additional forms. One is a bill of materials covering all generations of a product in digest form so that it can be used by process engineers and assembly supervisors. The other is a combined parts list for the purchasing and receiving departments.

None of these three lists does what it was intended to do, and errors and discrepancies become alibis in every production meeting. Checkoff systems are unworkable and it is still necessary to prepare select sheets, shortage lists, receiving reports and purchase requisitions. Moreover, the problem of maintaining this unwieldly mass of duplicative information discourages generation after generation of engineers and draftsmen.

The important lesson here is that if drafting exists there will be a drafting system whether it is recognized or not. It will be profitable, therefore, to analyze the needs of the business in advance and to set up a system to satisfy them. Otherwise, the system will grow like weeds on a garbage dump, and will finally have to be over-

Photo, courtesy Exide Storage Battery Co.

". . . a drafting system is more than light lines or heavy lines . . . it is a body of decisions and agreements . . ."

hauled after it has gotten out of hand and done a lot of harm.

A typical method of organizing a set of drawings which may well serve as a point of departure is given in TABLE 1.

This method or organizing drawings will usually be proof against rotation of personnel and changes in method of manufacture. It will provide part numbers for parts which have to be stocked or transferred without wasting them needlessly and confusingly on subassemblies which appear only transitionally and which vary in their makeup according to the size of the order and the skill of personnel.

Such a set of drawings is very easy to refer to, because there are so few generations from the first drawing to the bottom of the pile. It therefore lends itself to the starting, stopping and changing of production, which can be one of the worst tangles in a large plant.

Up to this point attention has been directed to general aspects of the drafting system and its inescapable effect on activities all over the plant. It is time now to consider in greater detail certain specific aspects of drafting from the same viewpoint.

Drawings and Other Documents: The first thing about a drawing is its number. A drawing without a number is worthless, because it can't be filed and found, specified or referred to with assurance. But what kind of number? It may be a part drawing or an information drawing, used locally or generally. If it is a part drawing, should the part number be identical to the drawing number, or different, or made by adding a suffix to the draw-

Table 2—Assignment of Drawing Numbers

1. Let there be one series of drawing numbers, running from 1- to 9-. This will permit use of small, four-digit numbers when the company is young, and simplify repeating the system intact in five-, six- and seven-digit numbers when the company grows up.

2. Code these numbers out in blocks, so that most of them are part/drawing numbers and a suitable few are reserved for information drawings. Let drawing and part numbers be identical, to avoid unwieldly cross-indexes and other confusion, and to afford simple identification for objects in process and in stock. Use these numbers for all parts, whether purchased, fabricated or assembled, with the possible exception of finished products which it may be desirable to stock by catalog number.

3. Use separate blocks of numbers for special parts and for general use, or standard parts. Use blocks of part numbers to identify classes of parts by material or finish, by source, by end use, or in whatever fashion will solve the peculiar problems associated with a particular business.

4. A suitable number assignment for some companies would be:

   100 000—Assemblies
   200 000—Castings
   300 000—Stampings
   400 000—Machinings
   500 000—Chemicals
   600 000—Electrical Apparatus
   700 000—Miscellaneous
   800 000—Screws, nuts, washers, etc.
   900 000—Information drawings and process specifications

5. A typical subdivision for each number group would be:

   300 000 up—Ribs and struts, special
   309 999 down—Ribs and struts, standard
   310 000 up—Panels, special
   319 999 down—Panels, standard
   320 000 up—Plates, special
   324 999 down—Plates, standard
   325 000 up—Brackets, special
   339 999 down—Brackets, standard
   340 000 up—Flanges, special
   347 499 down—Flanges, standard
   347 500 up—Housings, special
   367 499 down—Housings, standard
   367 500 up—Cans, special
   379 999 down—Cans, standard
   380 000 - 384 999 — Miscellaneous
   385 000-399 999—Unassigned

6. Avoid the use of letters or punctuation marks in part numbers as they are hard to remember and to manipulate with mechanical tabulating systems which can save a lot of money when a business is above a certain size.

7. Do not attempt to code the complete descriptions of parts into their numbers, with the possible exception of simple things like the most commonly used group of screws and washers, where feasible systems have been worked out and are in use. A complete code system will sink of its own weight; a partial one can be a life saver. A typical code is shown in *Fig.* 1.

8. Assign consecutive numbers to similar parts shown on the same drawing, and leave extra numbers if there may be additions to such a series.

ing number? Should number assignment be random and arbitrary, or should it carry coded information about the parts? The set of principles in TABLE 2 will help, and will make sense in almost any business.

Information drawings are those which identify no object by describing and specifying it, but furnish auxiliary data describing some aspect of one defined elsewhere. Wiring drawings and schematics, adjusting specifications and testing requirements, view sheets and special notes on finishing, potting and impregnating, running-in of gears, welding and similar design features; all are information drawings rather than part drawings. They contain no material lists and generate no components, but are appended to the family tree to add information. The drafting room must keep this straight, or the production control people may have a good excuse for material shortages.

In a good, tight set of drawings it is possible to start with one sheet of paper and pull successively every bit of information about the product at every level all the way down to raw material. There are no loose ends like, "It's not on the drawing but everyone knows you have to do that", to force renegotiation with subcontractors who bid in good faith by the papers.

A good drawing is easy to use. It carries next-assembly references back up the chain to every drawing on which it is specified. It carries a change record in such detail that a draftsman could change it back the way it used to be from the notes in the record column, *Fig.* 2. It indicates the class of urgency with which each change was introduced and the serial number of the change notice authorizing it. If it has ever been redrawn or renumbered or has superseded another part, it says so, and the old tracing is in file as a permanent record of the company.

No drawing should be changed without issue of a change notice, if it is used in production at any step from the order desk to the billing clerk. This notice must be properly approved to avoid unnecessary expense, and must give the nature of the change, the reason for it, and the urgency

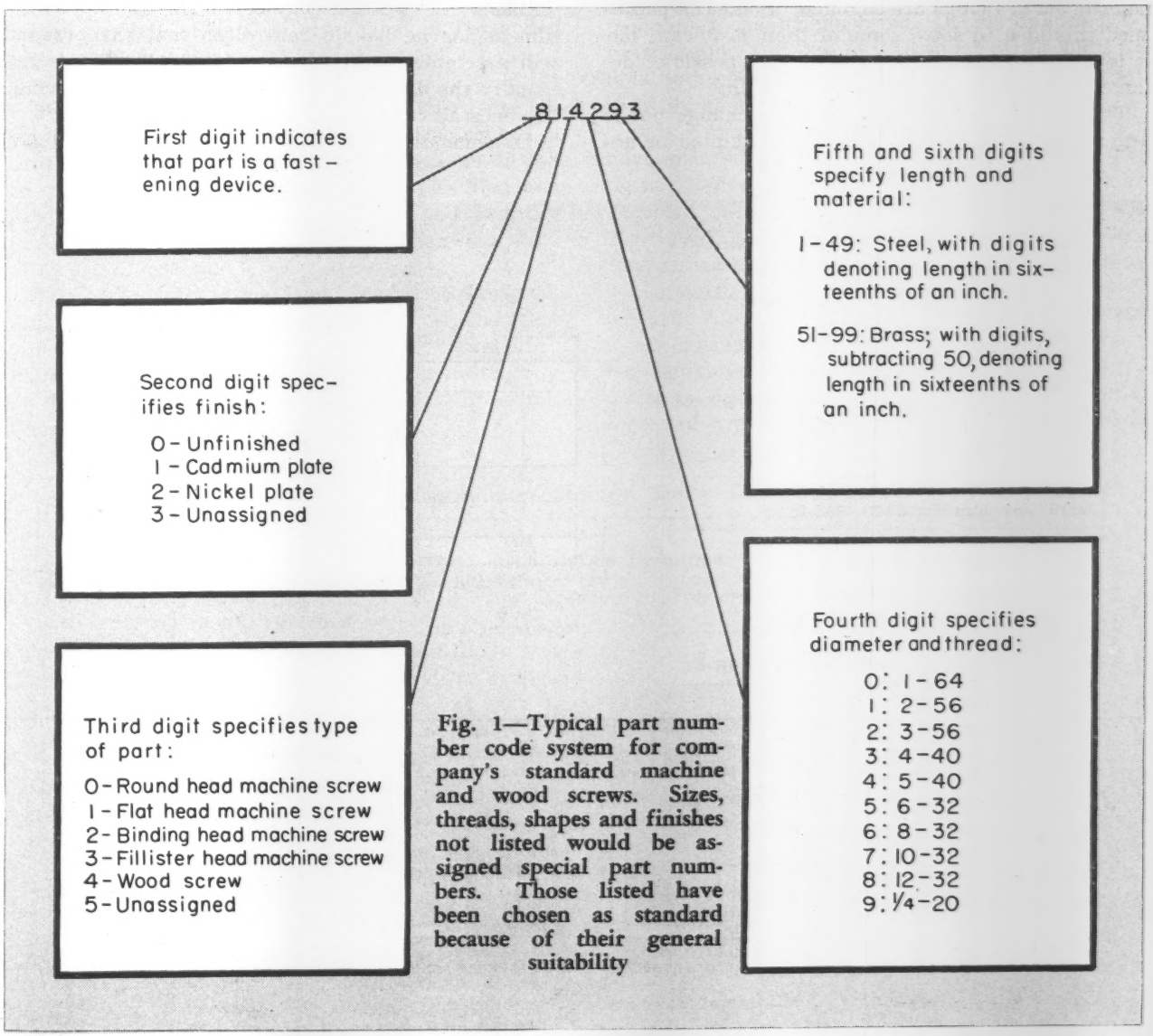


Fig. 1—Typical part number code system for company's standard machine and wood screws. Sizes, threads, shapes and finishes not listed would be assigned special part numbers. Those listed have been chosen as standard because of their general suitability

with which it is to go into effect. It may also convey other information. A good plan is to use one change notice for one design change regardless of the number of drawings which must accompany the notice and be listed in it. Co-ordination is tighter and there is less likelihood of having the new bolts reach the assembly line with the old nuts.

Urgency classes can readily be coded for simplicity. Such a code saves a lot of writing and reading and helps people get into the groove on putting changes through. But the code must be simple. It is confusing to use two codes in the same plant, like one company where no one has the slightest idea how urgent a Class B change is until he finds out whether it is a "change order" or a "change supplement."

Deferred changes are a special idea. Some companies refuse to tolerate them. They permit issue of a change notice only when the change is to go into effect, and the drawings are changed with it. Other companies let the engineering department issue the change and the new drawings while the idea is fresh, and if the urgency is low they have the production control people watch for a good time to put it through. A drafting request is then issued and the old drawings are changed. Some companies need this idea to solve some of their problems, but it is wise to stay out of it as long as possible; deferred changes require constant policing.

The following is a fairly complete change notice urgency code system, which can be adapted or abbreviated to fit the needs of any plant. It recognizes deferred drafting.

1. Assign to each engineering change notice one of the urgency classes listed in TABLE 3 and suffix the class designation to the serial number of the change notice, as ECN-9999-C2.
2. In the case of class C changes, it will be necessary to include the full text of the classification note directly in the change notice, and in the case of class A-3 changes, a brief note. For the other classes, the meaning of the symbol may be included or may be distributed separately as part of the standard business instructions.
3. Class A changes may require a high level of written supervisory approval before release.

The Dimensioning Problem: One of the places in a drafting system that always binds is the philosophy of dimensioning. It takes a lot of grease to keep it running smoothly enough to please everybody. Basically, there are three standard methods of dimensioning to choose from, dimensioning for manufacture, dimensioning for inspection, and dimensioning for use, *Fig.* 3.

Dimensioning for use is the only one that entirely satisfies the design engineer. He knows which dimensions he has to control so that the product will assemble readily and operate well. These are usually the dimensions he specifies on the drawing, the ones he cares about.

Dimensioning for manufacture comes to the fore

Issue - 1 1-3-38 1/2 dim. was 9/16 (CO-297-B)
Issue - 2 1-10-38 Holes were 1/4 drill (CO-301-B)
Issue - 3 2-4-41 12-24 NC-2 tapped hole was spec. 3/8 from bottom, 1/2 from left. (CO-527-C)
Issue - 4 2-27-43 Nickel plate .0002 thick was spec. (CO-829-C)
Issue - 5 4-8-43 Mat'l was clock brass. (CO-1043-D)
Issue - 6 4-19-43 Mat'l was leaded brass. (CO-1841-D)
Issue - 7 8-2-47 1/16 dim. was 1/8. (CO-2073-B)
Issue - 8 9-17-50 .005 max. radius was not spec. (CO-2548-C)

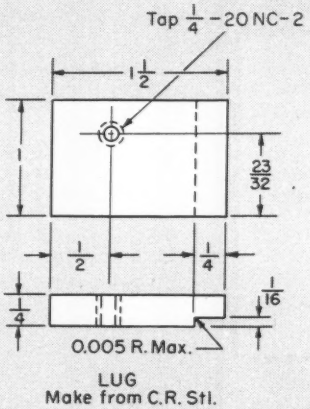


Fig. 2—Example of complete drawing change record which provides detailed history of revisions right on the drawing

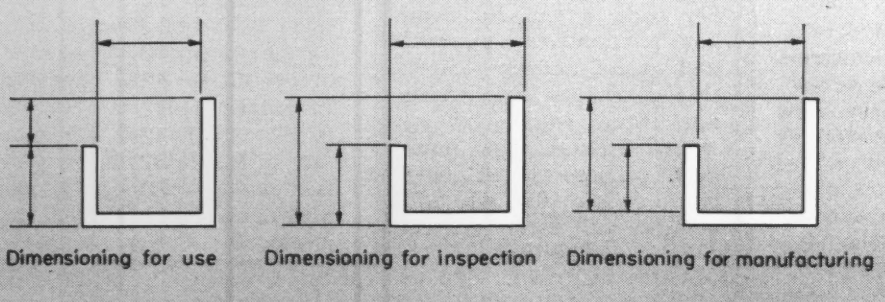


Fig. 3—Orientation of drawing dimensions for three different functional requirements—

about every other time a layout man or toolmaker makes a mistake in arithmetic which costs money or time ill-spared. The operating people want everything laid out in co-ordinates for the jig borer, or referenced to the easiest face to clamp the casting down on. Or they want all bends dimensioned to the inside, or they want centerline dimensioning.

Dimensioning for inspection comes up when somebody hangs the error on the inspection department, and they tell the world that nobody, but nobody, could build a gage to check that part the way it is dimensioned, so why not be realistic? No swinging radii from centers located in space by projecting spiral curves, no locating holes from imaginary centerlines in unsymmetrical parts, no plus-or-minus 0.005-inch in sponge rubber disks. Just horse sense. "We'll give you what you want, but please want something you've got a chance of getting!"

The philosophy of dimensioning becomes an issue about every so often, and someone has to pacify everybody, convert rancor into enthusiasm and get things back into high gear. It must be decided whether engineering is unrealistic, whether production demands are prohibitively expensive, whether inspection is just covering up for a boner, and minor conflicts of local interest must be reconciled into a unified company effort.

Mechanical Aspects of Drafting: There are always certain choices on the mechanical side of a drafting operation. Shall original tracings be ink or pencil? How securely shall they be filed and held? What reproduction processes and facilities are needed? Who gets prints, and under what kind of a control system?

The best drafting materials are none too good. A master vellum can wear out in six months from handling, changing and printing, and take sixty hours to redraw because it is too far gone to copy by optical process. Poor pencil smudges. Poor ink flakes. Poor tracing cloth cracks.

MANAGEMENT OF DRAFTING

The best of care is none too good. With proper care a pencil transparency should last five or ten years at least, and ink on cloth should last several times as long. Proper care of tracings means keeping a print file for reference and letting only a few approved persons handle tracings. It means putting them away when not in use. And it means printing from an intermediate copy if the print load is heavy. Everyone must handle a tracing as if it is worth the hundreds of dollars it has cost and would cost again for replacement. Tracings should be kept in as good cabinets as the business can afford, perhaps in fire-resistant ones. If master drawings were lost, would it put the company out of business?

Any company needs to get the most it can out of optical reproduction processes. There are circumstances in which to use an intermediate transparency to print from, such as an Ozalid Sepia or a Van Dyke. Draftsmen should take full advantage of reproduction of tracings when it is necessary to redraw or to make up new drawings resembling old ones. Substantial savings are possible if the techniques can be mastered. Eight dollars for a reproduction and one day to touch it up and alter it is both cheaper and quicker than twelve days to draw by hand.

It is a matter of policy as to who is allowed to have prints of drawings and how many, or how tightly it need be controlled. First, prints are expensive. Second, they are easily carried away. Third, old issues can be used in error. One company releases only four copies of each drawing, which must be signed for and must be turned in when new issues are ready. This is print control; it is expensive, too. Another company permits each employee to requisition as many copies as he needs to do his job, and often runs off 70 or 80 copies of a new drawing. Waste of prints can be

Table 3—Engineering Change Notice Code System

Urgency Class	Code Definition
A-1	Apply this change to all units accessible for conversion, including those in the hands of the customer.
A-2	Apply this change to all units not shipped.
A-3	Apply this change to all manufacture except . . . (quantity) . . . units required for urgent deliveries
B	Apply this change so far as can be done without repacking, retesting, readjusting or reassembling. Apply to all parts on hand and to all parts in process of manufacture.
C-1	Apply this change . . . (engineer to specify precisely) . . . Typical wordings are as follows: Apply to all units not tested. Apply to all gear trains not yet mounted. Apply to all units to be shipped after May 1, 1954.
C-2	Same as C-1 except that drawing changes will be deferred instead of immediate.
D-1	Apply this change as soon as new parts are available. Drawing changes deferred.
D-2	Apply this change as soon as can be done without interfering with production or incurring loss through scrapping or conversion of material.

cut down by strategic placement of neat, accessible print files, preferably in books. It can also be cut down by returning all surplus prints and leaving it to the reproduction organization to throw away those which are obsolete.

Standards and Standardization: There are always pros and cons to the question of standards. One person or another may be either violently for or violently against standardization, and this emotion must be discounted in order to assess the true values involved. For standardization, like hard cider, is good up to a certain point.

Standardization is never good for its own sake; it is good only because of definite advantages it brings. Standardization should never be used as the reason for doing something. It is better to use the real reason, the specific advantages which will be gained from standardization, to keep people on the track.

Standardization can be overdone. A program which cuts down the number of gear types kept in stock from 7200 to 485 will do a lot of good in terms of set-up charges, stock and investment control, tool maintenance and small lot purchasing, but if it stultifies the design department so that next year's model and the year after's no longer hold leadership in the field, there probably are no real savings.

The place for standardization is at the beginning of design. After drawings are made up and tools in process it is too late to gain most of the savings. The amount of standardizing depends on the nature of the product. Some companies can standardize their whole outgoing lines with tremendous benefit to their customers as well as themselves. Others can standardize only the general-use parts, which may mean nuts and bolts, or gears and bearings, or resistors and capacitors.

Standardizing must be by design and procurement, not by cowpath. Standard components must represent good, rational engineering and it must be easy for everyone in the company to use them. No standard is ever going to do any good if the standard parts are the hardest ones to get; even the engineers won't have time to put them in new designs.

One large company standardizes by cowpath. It considers any part a standard part if it happens to be a stock item right now, which places design at the mercy of stock control and results in the total absence of standards. This same company specifies drilled holes in terms of a standard which has never been implemented. Its standard drills are unprocurable and every mechanic works with a cross-reference chart from the drawing to the drill stand.

A standard must be good design, it must be procurable, and it must be *implemented up to the hilt.*

Decimal Dimensioning: Decimal dimensioning is a reform which may or may not be wise for a plant. Like every other question, it has at least two sides.

Decimals are easy to manipulate. In our civilization it is considered unreasonable to expect a toolmaker to multiply MCDXIX by XLVI, but it seems normal to expect him to add 11 21/32-inches to three times 1-foot 9 37/64-inches. And the English use pounds, shillings and pence, guineas, crowns and farthings for money! It is no wonder that one large company had trouble with its evening school course in blueprint reading.

The course was well attended, but the teaching staff found it going over the heads of the students. Week by week they pitched it lower, and finally found an acceptable level when they were teaching the basic arithmetic of adding and subtracting fractions and mixed numbers. That was the toughest part of the blueprint reading, the arithmetic! And it, of course, was a by-product of the fractional dimensioning.

The indirect costs of fractional dimensioning to American industry must be simply staggering, in view of all the errors, all the double checking, all the arithmetic time, and all the effort wasted in coverup so the boss and the engineer won't find out how stupid people can be afraid people will think they are.

Some people reject decimal dimensioning because they think it will eliminate keyed tolerances. It is common to use decimal or fractional notation to show which of two tolerances is to apply and this is impossible if all dimensions are decimal. But a star or an underline will serve equally well.

No business can afford to get involved in decimal

"... proper care of tracings means keeping a print file for reference and letting only a few approved persons do the handling ..."

Photo, courtesy Boeing Airplane Co.

dimensioning (or the metric system) unless it is prepared to carry through from beginning to end. This is a case where half a loaf is worse than none. Decimal dimensioning means decimal designing; it does *not* mean having the draftsman translate fractions into decimals and the mechanic translate them back again. Designers must think in decimals and use decimal rulers. Shop tools and machines must read in decimals so that everyone can operate without any translating.

A good job of decimal dimensioning will pay off over the years, but a job half-done will be a costly blunder.

Point of Diminishing Return: This point must be watched for. Any system can go past it if left to itself. Decisions must be made and periodically reviewed on such matters as the following:

1. To what extent shall quality derive from general job knowledge of workmanship and to what extent shall standards be prepared in specification, drawing or handbook form?
2. To what extent shall dimensions, tolerances and material specifications be omitted from drawings, with reliance on job knowledge and trade practice?
3. To what extent shall performance requirements for the product depend on the job knowledge of experts grown gray in the business, and to what extent shall they be incorporated into written specifications?
4. To what extent shall process requirements, like the type, position and quality of welds, be specified instead of being left to the discretion of the operator or of the set-up man?
5. To what extent shall commercial material be purchased to vendor's catalog and to what degree shall written specifications be used to protect against changes and substitutions?

A manufacturing operation is like a three-legged stool. Its three legs are quality, costs and schedules. To keep the operation in balance, there must be equal importance and equal weight on each of these three. Emphasis on one alone will get results, often spectacular results. Emphasis on two will give an impression of orderly, systematic, efficient operation. But it takes the proper division of weight among the three to keep things right side up over a long period.

It will be the contribution of the drafting system or lack of system, in these three areas which affords the basis for choice. It is necessary to consider the influence of the drafting room on overall plant costs, outgoing quality, and production schedules. Intelligent evaluation must weigh how much trouble there has been, how much trouble there is, how much trouble there will be in future. Moreover, in doing this an investigator must remember that he is looking for comments on a system of communication, and that weaknesses in such a system are often concealed because no person on the receiving end of communications can charge deficiencies to the system without laying himself open to a countercharge of deficient understanding.

Among the factors to be considered are:

1. How many employees are there and do they know each other well enough to keep their job knowledge continuously pooled?
2. What is the turnover rate among those employees and supervisors who are depended on to maintain the continuity of job knowledge from generation to generation?
3. Are there many and complex products so that it takes a long time for an employee to learn the ropes?
4. Is manufacture continuous or intermittent, and do products become obsolete rapidly before the know-how to make them can be lost?
5. Does the business expand and contract rapidly with the season of the year, the business cycle, or the international situation?

If a business is simple and stable, it doesn't need drawings at all. The employees will know what to do and how to make the product without them.

If a business is complex and stable, it will need drawings, but they can be produced economically. They can use company standard short cuts and conventions to such an extent as to constitute a com-

". . . select a drafting system which is adequate for all foreseeable requirements imposed by healthy expansion . . ."

Photo, courtesy Exide Storage Battery Co.

pany shorthand system. And the simplicities will save enough to pay for increased training of new employees.

If products are short-lived, perhaps limited to one production run of a few weeks for each design, there won't be much trouble unless they are extremely complex. Word-of-mouth information and samples will be adequate.

But if a business expands and contracts rapidly, being called on to take seasonal and other shock loads, or if for any other reason there is a high turnover of personnel, this is the danger signal. It needs drawings of complexity adequate to the product, and can't take short cuts in preparing them. The information has to be on paper, and it must be easy to understand, so that a new employee can do things right the first week.

Any considerable change in these factors of complexity and stability will call for a review of previous decisions on the drafting system, since it will change the point of diminishing return.

Public and Personnel Relations: The impact of drawings on employees, customers and vendors is easily overlooked, but important. Here as elsewhere, the point of diminishing return must be gaged accurately, or allowance made for inaccuracy. And good drawings cost little more than poor ones.

Fluid Brake Controls Downhill Truck Speed

A NEWLY developed brake absorbs kinetic energy in a manner similar to a fluid coupling, the difference being that the driven member or turbine of the coupling is the very solidly anchored brake housing. Consisting of a rotor, housing, and control valve, *Fig.* 1, the brake is used in conjunction with a torque converter and automatic transmission to control downhill speed of large, off-the-highway trucks, *Fig.* 2. The brake housing is fastened to the torque converter housing and the brake rotor is splined to the torque converter output shaft. Developer of the brake is Allison Div., General Motors Corp.

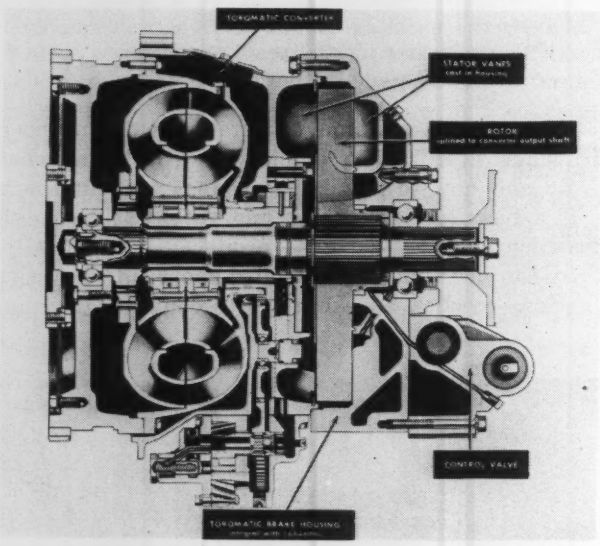


Fig. 1—Cutaway view of Allison Torqmatic converter and brake

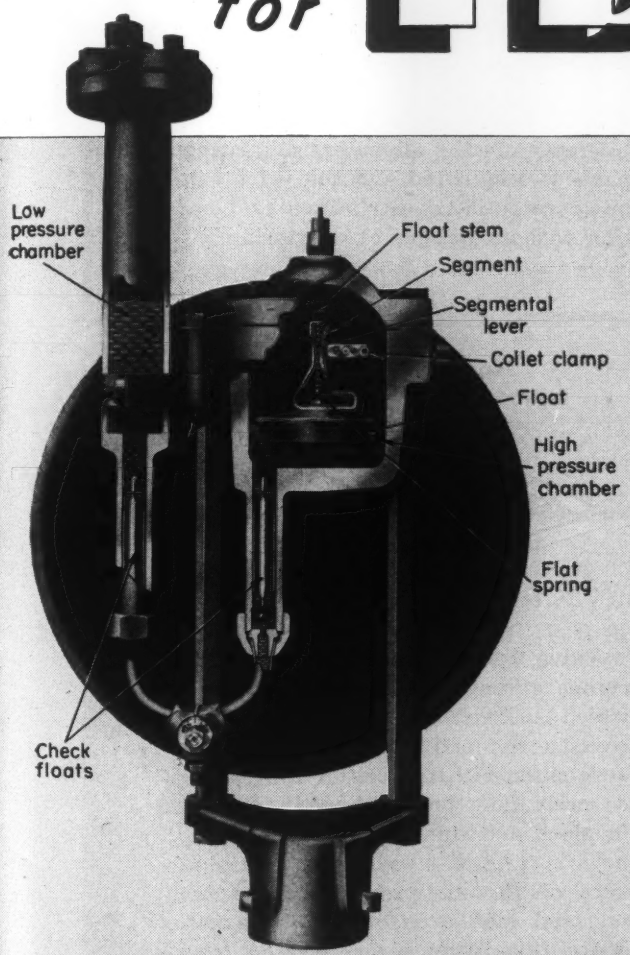
As the truck moves downhill during operation, the operator applies the brake by opening the control valve at the back of the brake housing to admit oil to the brake. Rotor blades churn the oil against the stator vanes, thus placing a drag on the converter-transmission drive shaft. Amount of braking obtained is proportional to the control valve opening. Conventional friction brakes need be used only when a complete stop is necessary.

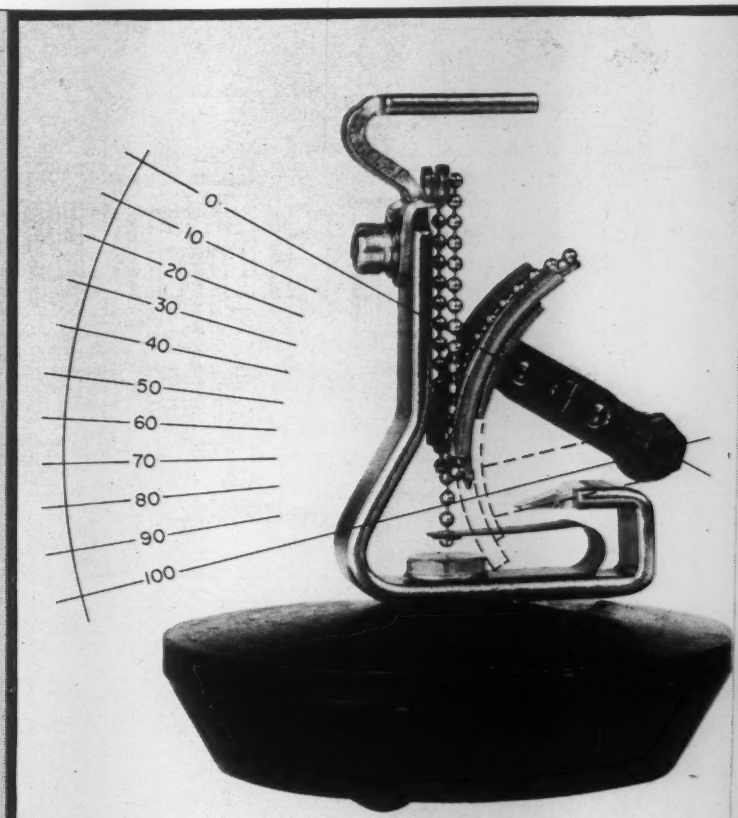
Fig. 2—Downhill speed of this 34-ton capacity truck is controlled by a fluid brake whose operation is quite similar to that of a fluid coupling

Heat generated by the braking action is absorbed by the oil. Pumping action of the brake is used to circulate the oil through a heat exchanger and then back to the reservoir which is also the oil source for torque converter and transmission.

"The engineer has a responsibility, which he is specially taught to carry—the responsibility for the application of scientific caution and scientific precision to the practical problems of our time insofar as that can be done. The general spread of a scientific scrupulousness would improve our politics, our social life, and our personal experience. Above all, in our time, the scientific caution which rejects easy answers for difficult questions is needed to combat the utopianism which is leading other nations into tyrannies and revolutionary violence."—DR. LYMAN BRYSON, *guest professor, Mechanical Engineering Department, Columbia University.*

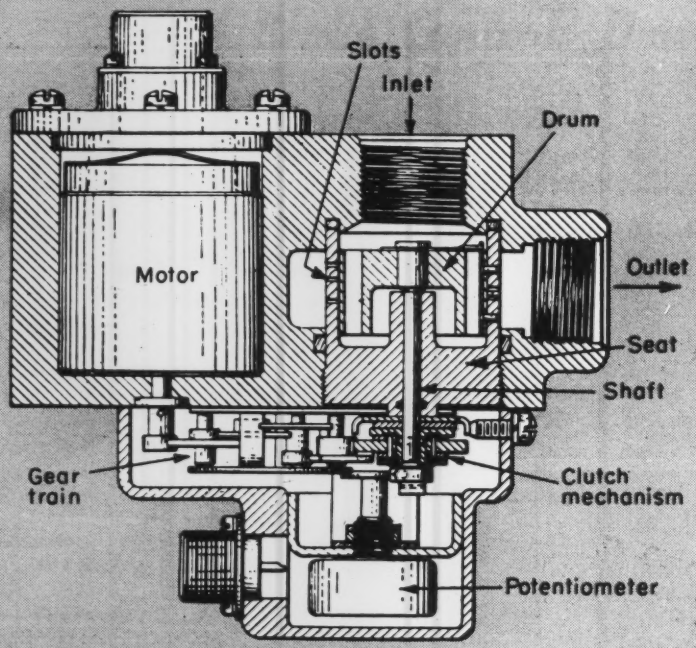
SCANNING the field for IDEAS

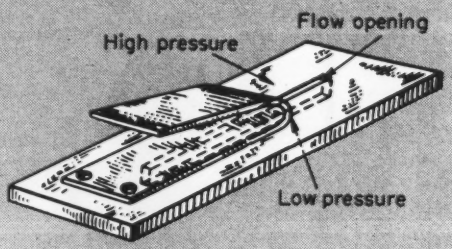




SEGMENTAL LEVER DESIGN of a flowmeter pen drive eliminates angularity errors and lost motion and improves instrument reliability. Developed by the Foxboro Co., the drive accurately transmits vertical motions of a float to the recorder pen, maintaining a constant linear motion relationship over the full range of angular pen travel. Pen position is controlled through a segment and lever assembly by means of two stainless steel bead chains of equal length which connect the bottom end of the segment face to the upper part of the float stem. A third chain, connecting the upper end of the segment face to a flat spring on the float, maintains segment position under tension and eliminates lost motion. As the float travels vertically in response to changes in flow, the chains wind and unwind on the arc surface of the segment to drive the pen in an angular path. Uniform pen motion at all float positions is assured by the design which maintains a common point of tangency between the three chains and the arc surface on the horizontal center line of the lever pivot; equal angular motions of the pen are produced by equal increments of float travel.

ADJUSTABLE FLOW RATE in a rotary valve for remote operation is obtained with a flexible flat belt. The Flexbelt valve developed by the Aircraft Products Div. of Manning, Maxwell & Moore Inc. employs a Teflon-impregnated glass fabric belt, mounted to a motor-driven drum, to control flow through slotted orifices in a cylindrical seat. Infinite variation of flow rates is possible with the design which operates effectively over a temperature range of −65 to 250 F at pressures up to 1800 psi and can handle up to 25 gpm of water with 25 psi pressure drop. Need for close tolerances in the alignment of seating parts is eliminated and the valve can be operated in the partially open position without danger of chattering.

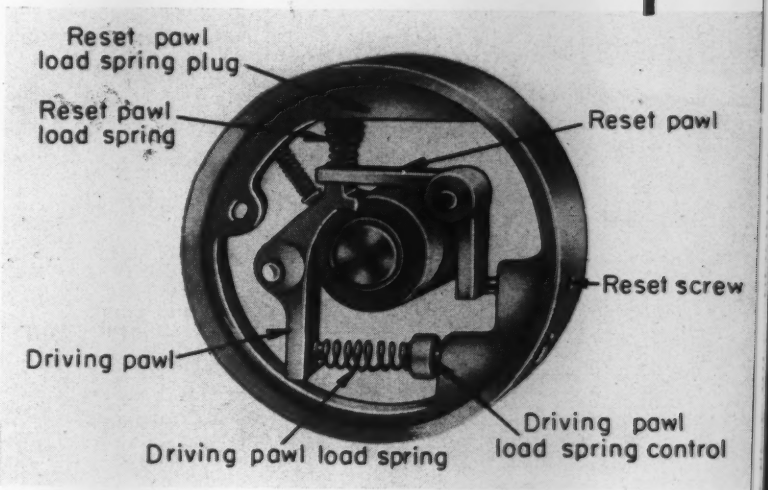




Valve operation is based upon a comparatively well-known principle in which a flexible belt is mounted to cover a slot orifice on the high-pressure side. With the orifice completely covered, fluid pressure holds the belt in place and flow is cut off. As the belt is peeled away from the slot, rate of flow is proportional to the exposed slot area. In the Flexbelt valve, the orifices are located in a slotted cylinder and the belt is rolled-up on an internal drum in the open position. Variation in flow characteristics to provide either a linear or logarithmic relation with valve movement can be obtained through modification of number, size and shape of orifice slots to meet specific application requirements. Operating power requirements are kept to a minimum by the design, offering advantages for application in automatic control systems.

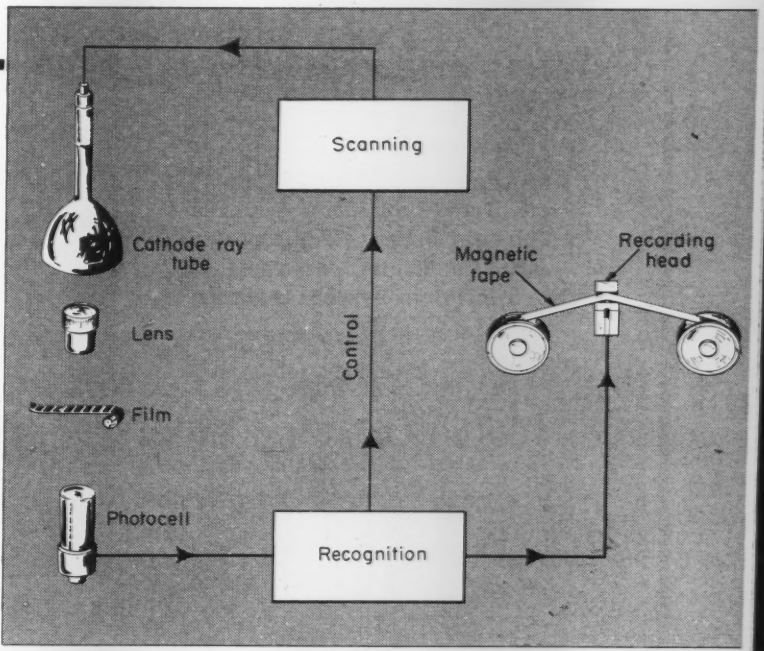
IDEAS

OVERLOAD TORQUE PROTECTION for shaft power connections, regardless of direction of rotation, is obtained with a trigger-action pawl mechanism in the new Trig-O-Matic clutch. Developed by Centric Clutch Co., the design operates instantaneously when an overload occurs and assures positive disengagement of the power members. In normal operation, power is transmitted to the driven member by a spring-loaded driving pawl which engages a V-shaped groove in the driving collar. When an overload occurs, the driving pawl is kicked free of the groove and engages a reset pawl, locking the clutch in released position. Re-engagement is facilitated by an external reset screw which actuates the reset pawl, releasing the driving pawl and permitting operation to resume at the cycle point of release. Adjustment of the spring loads on both pawls, which is readily accomplished through screw and plug attachments, permits clutch action to be varied to meet different design requirements.

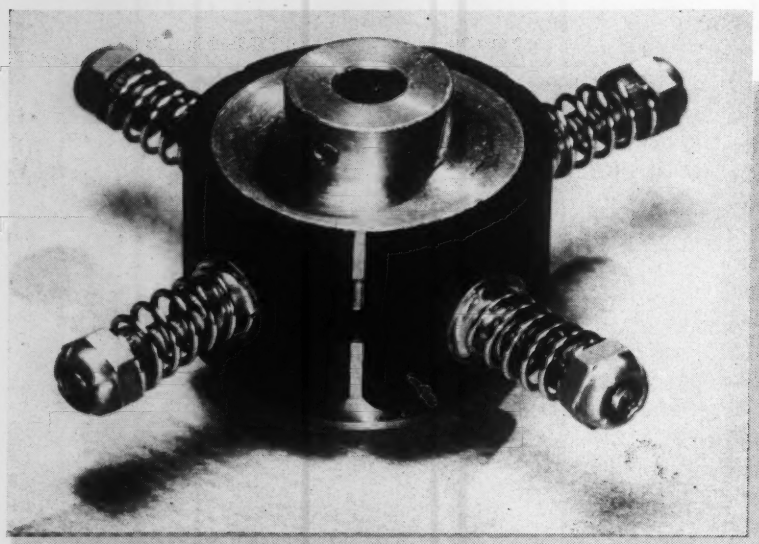


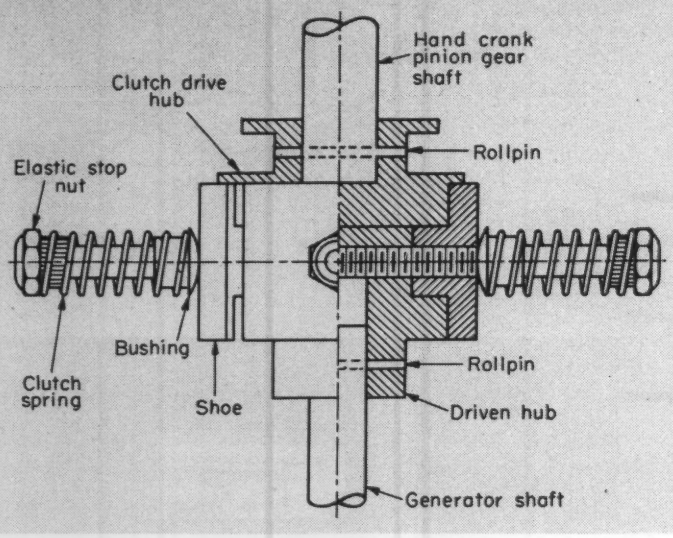
OPTICAL DATA TRANSLATION converts written records directly to magnetic form for processing and substantially reduces the time-consuming paperwork required by conventional techniques. Named FOSDIC (Film Optical Sensing Device for Input to Computers), a unit developed by the National Bureau of Standards for use with large-scale electronic computers "reads" microfilmed copies of written records that have been code marked with an ordinary pencil or pen and automatically processes the coded information into electrical pulses which are recorded on magnetic tape ready for use.

In operation, the microfilm is scanned frame-by-frame by a cathode-ray tube with a moving spot which actuates a photocell to produce varying electric signals corresponding to the amount of light passing through the film. Total time required per frame is about 1¼-seconds and maximum reading capacity for legibility is about 2800 marks per frame. Advantages of the optical scanning unit include increased freedom in record layout and size selection; reduced cost of paper stock required; added allowance for weight and position of markings; and increased tolerance for mishandling of records. Evaluation tests of the system in actual computer operations indicate that the transcription process through the new unit, including filming, does not appreciably add to other sources of error in the enumeration process.



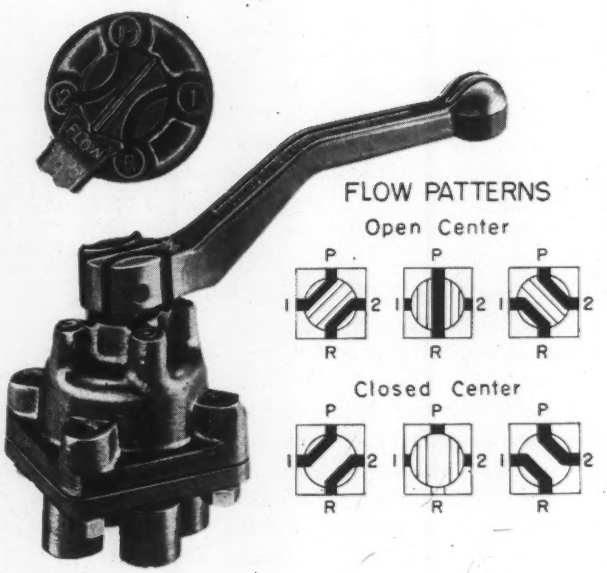
IDEAS





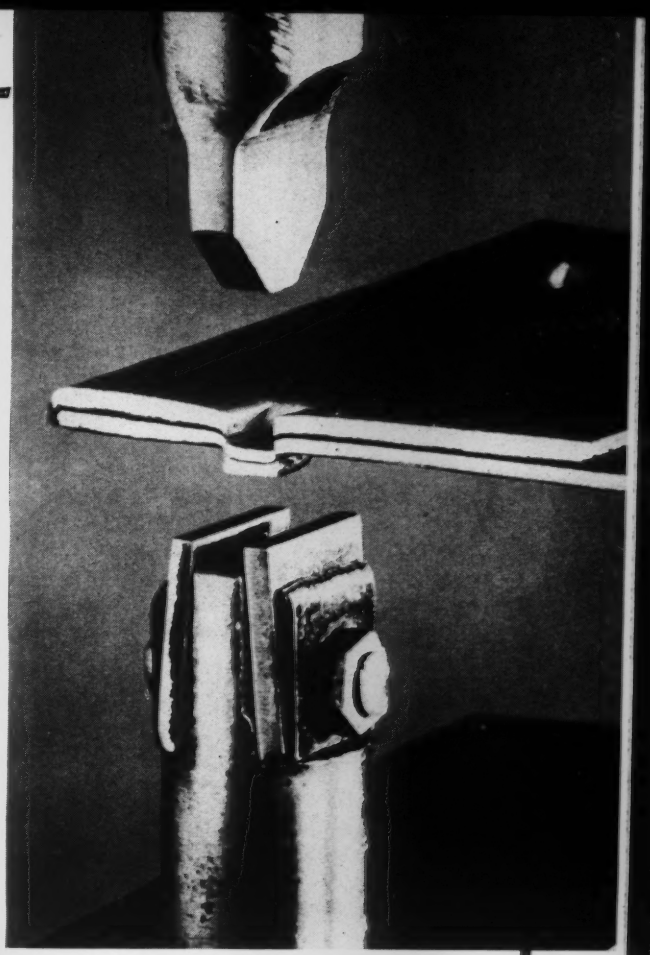
CENTRIFUGAL SLIP CLUTCH developed by Winslow Co. offers a simple rugged construction and can be preadjusted to disengage automatically at a prescribed shaft speed. Designed for a megohmeter hand-cranked dc generator unit, the clutch is used to limit generator speed to a safe value and prevent excessive voltage buildup when the hand crank is turned. Clutching action is produced by four spring-loaded Bakelite shoes, mounted to radial studs on the driven hub, which ride in and out in response to shaft speed to engage and disengage the surfaces of the driving and driven hubs. Adjustment of spring pressure to vary the speed of disengagement is readily accomplished without disassembly through clinch type Elastic Stop Nuts which serve as spring retainers at the end of the studs. Clutch construction, which also employs Esna Rollpins and eyelets instead of screw machine parts used in previous design, provides a vibration and wear-resistant unit which facilitates assembly and maintenance.

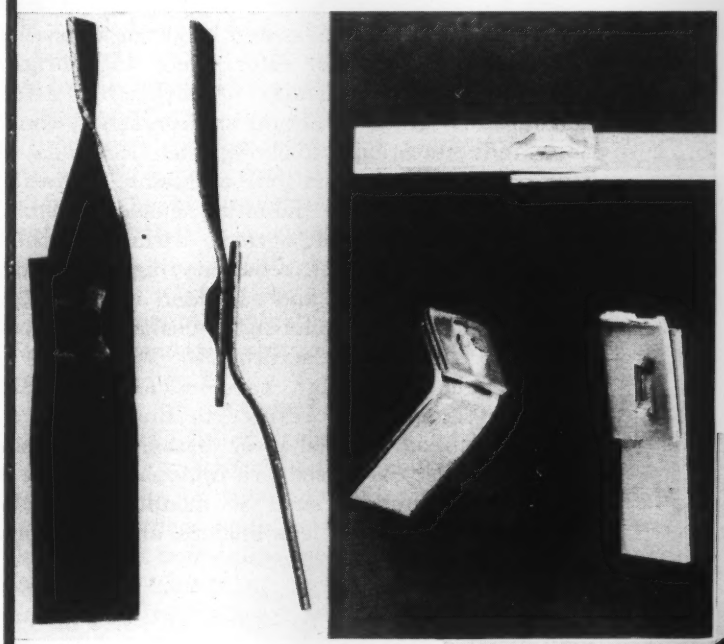
BUILT-IN FLOW DIAGRAMS indicate fluid path and facilitate control of Barksdale manual valves. Raised and painted line patterns on the valve control handle match numbered or numeraled stations on the valve body to indicate porting arrangements for all actuating positions. Utilized on both four-way selector valves and two-position shut-off valves, the design simplifies valve operation and assures ease of visibility.

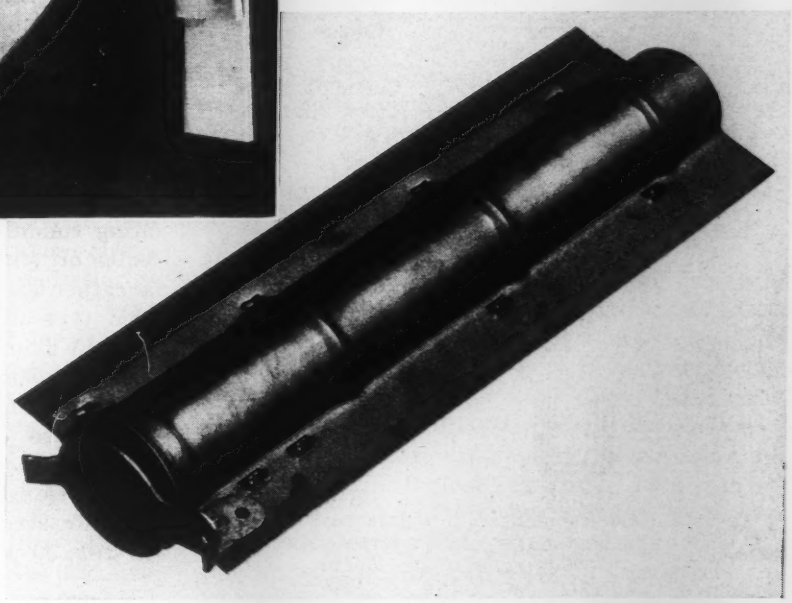


IMPACT FASTENING of sheet metal assemblies by means of a one-step press operation eliminates conventional rivets, bolts and welds and meets design requirements to cost advantage. High producibility is achieved through a new approach to sheet metal fastening which utilizes the shearing action of a special punch and yieldable die set to form a permanent fastening wedge of the parent metal on the surface of the sheet joint. Strength and bonding qualities of the joint formed, as indicated by experimental tests, are comparable to those obtained with conventional rivets.

Developed and patented by Ivan A. Williams, who has granted sole licensing rights to the Crockatt Engineering Co., "Metalacing" is suitable for use with any material which can be sheared, drawn and upset, including the standard sheet metal types, in thickness up to ¼-inch. Dissimilar metals, such as steel and aluminum, can also be readily joined. A particularly striking example of the possibilities offered by the new process is furnished by a formed tubular sheet-metal box design in which fabrication costs were reduced by over 20 per cent as compared to a previous spot-welded construction. Pickling and other cleaning operations were eliminated and the use of prepainted scrap metal, which was made possible, reduced material costs.







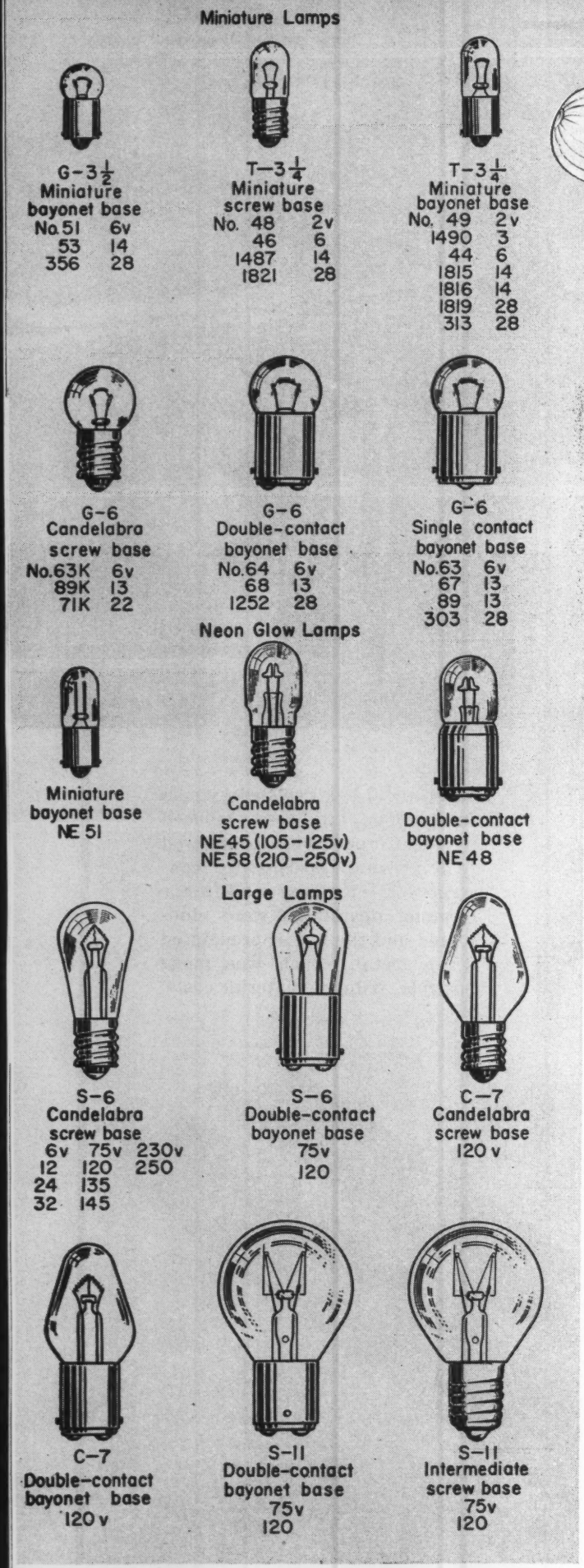


Fig. 1—Left—Several commonly available pilot-light lamps with typical bulb and base combinations

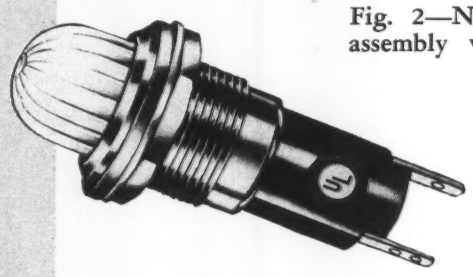


Fig. 2—Neon lamp pilot light assembly with built-in current-limiting resistor, dome-shaped cap, and solder-type wiring terminals

Selection and Application of

SELECTION of a pilot-light assembly for a specific application requires careful weighing of several design factors. Obviously the intended purpose or function of indicator or pilot lights is of primary importance in dictating specification of pilot-light details. Knowing in detail the pilot-light function and its probable ambient light environment, the designer can then determine jewel brightness and brightness distribution, and desired jewel color along with brightness control requirements. Additionally, attention must be given to actual environmental conditions and limitations involving such items as air temperature, air circulation, corrosion, vibration, shock, etc. Available mounting space, assembly mounting or attachment options, wiring accessibility, appearance, lighting reliability, light assembly and lamp initial cost, and ease and cost of lamp replacement are all pilot-light design considerations warranting close scrutiny.

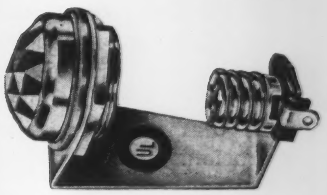
As a guide for design, this article summarizes pilot-light lamps with respect to the various options of sizes, bulb shapes, bases, and design voltages. Also discussed are optional features of pilot-light assemblies such as mounting-hole size requirements, types of lens holders, and lens shape, color, and surface.

Pilot-Light Lamps: To satisfy all sorts of operating conditions, lamps (often referred to as lamp bulbs or, simply, bulbs) are commonly available in a rather extensive variety. Of course, lamps for this type of service are small—usually under 1 inch in diameter and less than 2 inches in overall length including lamp base.

Pilot-light lamps with screw bases fall within three size classifications—miniature, candelabra, and intermediate. TABLE 1 gives a base-diameter comparison for these lamps. The larger intermediate screw type is usually not selected except in 210-250 volt applications.

Information on which this article is based has been supplied through the kind co-operation of R. E. Greene, Dialight Corp., Brooklyn, N. Y.

Fig. 3—Open type pilot - light unit with solder type wiring terminals



PILOT LIGHTS

Bayonet-base lamp types are made only in miniature and candelabra sizes as can be noted in TABLE 1. Bayonet-base pilot-light lamps are being chosen more and more because this design provides greater assurance against light indication failures that sometimes occur when the screw-base type loosens in the socket from vibration. In the miniature size, bayonet bases are produced only in the single-contact construction while both single and double-contact bases are commonly employed in the candelabra size designs. In designating the miniature bayonet size, it is necessary to always preface the specification with the word "miniature." The candelabra designation is frequently omitted when specifying the candelabra bayonet-base size, and the lamps or lamp bases are then simply referred to as either single-contact bayonet or double-contact bayonet.

Both base and bulb shapes common for pilot-light lamps are shown in *Fig.* 1. These glass bulbs are conical, globular, pear-shaped, or tubular in contour. Standard letter designations for such bulb shapes are C for conical, G for globular, S for pear shaped, and T for tubular. The maximum diameter of the glass bulb is given by the number following the bulb-shape letter designation and is measured in eights of an inch. For example, the most commonly used lamp has a T-3 ¼ bulb designation which is recognized as a tubular bulb with a 13/32-inch diameter. Complete lamp specifications are sometimes given by such bulb designations as C-7, G-3 ½, S-6, T-3 ¼, etc., but these terms are actually incomplete. A full description requires additional mention of base type and electrical rating in volts and amperes or watts.

Miniature lamps are usually specified by lamp number and voltage as indicated in *Fig.* 1. The neon types are completely specified by such designations as NE 45, NE 48, NE 51 and NE 58 and no voltage specification is really required. When referring to "large" lamps, the bulb-shape and size designation shown in *Fig.* 1 is usually preceded by the approximate lamp wattage and followed by the rated lamp voltage in parentheses. For example a 6S6(120) specification means a 6-watt, S-6 bulb, 120-volt lamp.

Because lamps generate considerable heat in producing light, small bulb size and low power ratings go together. It is nearly impossible to design incandescent lamps for 110-volt circuits with power ratings as low as 3 or 4 watts because the small-diameter filaments required are too fragile for satisfactory service. For that reason few miniature lamps are designed for more than 28 volts. There are "large" lamp pilot lights designed for voltages ranging from 105 to 250 volts with 6 to 7-watt power ratings and some designed for voltages from 210 to 250 volts with 10-watt power ratings.

Table 1—Pilot-Light Lamp Bases

	Base Size		
	Miniature	Candelabra	Intermediate
Bayonet Base			
Contacts	Single	Single or double	....
Max. diam., in.	0.364	0.603	....
Screw Base			
Max. thread diam., in.	0.375	0.465	0.651
Threads per inch	14	10	9

Miniature incandescent lamps are usually designed for voltages in the range from 2 to 28 volts and have current ratings from 0.060 to 0.5-amperes. The latter rating is found only in the lower voltage types. High-current and low-voltage lamps are by far the most rugged types for all types of service.

Neon glow lamps are rapidly finding more widespread usage in indicator service. Although neon lamps will not operate on voltages much below 100 volts, they have no upper voltage limit if employed with the proper dropping resistor. Those types which have screw bases are rated 105-125 volts or 210-250 volts, but small additional re-

sistors extend these ranges. The entirely unique NE-51 glow lamp can solve many design problems. It compares in size to the miniature types and consumes less than 1 milliampere of current and may be connected to any voltage above about 100 volts with the proper current limiting resistor. Enclosed pilot-light fixtures are available in a wide variety of forms that have built-in resistors for neon lamp operation. Some of these fixtures, *Fig.* 2, are designed with dome-shaped, lenticulated cover caps that add much to the effectiveness of the small amount of orange-red light produced by neon lamps. Neon glow lamps are little affected by overvoltages and have effective life ratings exceeding 10,000 hours. They do not burn out but become gradually dimmer and should be replaced before lighting effectiveness gets too low.

As the designer approaches the selection of a lamp bulb for equipment the most important consideration is the voltage available to energize the lamp. Choice of lamps is broad when either line voltage or low voltage from a transformer may be used. A miniature lamp in a T-3 ¼ or G-6 bulb may be selected and operated on low voltage from a transformer, or either a neon or "large" lamp may be chosen to operate on line voltage. Final decision will rest on such factors as size of pilot-light assembly and its adaptability to equipment size, brightness and color of the light emitted, lamp heating effect, life performance that may be expected of the lamp for the duty cycle, available mounting space, and insulation and wiring considerations. An incandescent lamp with a slightly higher voltage rating than operating voltage can usually be employed with some advantage in the form of longer life, but of course lamp brightness is reduced.

Most of the lamps shown in *Fig.* 1 are those from which a choice should be made if at all possible. The list is sufficiently complete to cover practically any condition except an odd voltage. While lamps for other voltages are made in several of the types shown, they are not readily available for replacement purposes.

Table 2—Lamp and Pilot-Light Assembly Selection Guide

	Low	Standard	High
Lamp			
1. Base Type	Miniature bayonet		
	Miniature screw		
	Single-contact bayonet (Candelabra)		
	Double-contact bayonet (Candelabra)		
	Candelabra screw		
	Intermediate screw		
2. Bulb Shape and Diameter	C–7		
	G–6		
	S–6		
	S–11		
	T–3¼		
3. Voltage Rating	2v	120v	230v
	6	135	250
	14		
	28		
Pilot-Light Assembly			
4. General Type	Enclosed		
	Open		
5. Unit to Accommodate Lamp Selected			
6. Bushings and Fastenings	Thin panel		
	Thick panel		
7. Mounting Hole Diameter	15/32 in.		1 in.
	9/16		1¼
	11/16		1½
	13/16		
8. Nuts Set for Front or Rear Insertion	Hex		
	Round		
9. Lockwashers	Split		
	Shakeproof		
10. Flange or Front Nut Finish	White nickel		
	Black nickel		
11. Socket Terminals	Soldering lugs		
	Binding screws		
	Wire leads		
12. Lens Holder Attachment	Screw		
	Friction		
	Bayonet		
13. Lens Holder Finish	Polished chromium		
	White nickel		
	Black nickel		
14. Lens Shape	Flat		
	Convex		
	Faceted		
	Torpedo		
	Dome		
	Stovepipe		
15. Lens Color	Red		
	Green		
	Amber		
	Blue		
	White		
	Yellow		
	Clear		
16. Lens Surface—Back Only or All Over	Matted		
	Frosted		
	Plain		

Pilot-Light Assemblies: When the designer has chosen the lamp bulb which meets his requirements, he can then proceed with the selection of the pilot light assembly in which it will operate. A pilot light assembly consists of a lamp socket, a bracket or bushing for supporting the socket and lamp, and a lens through which light is emitted. These units are either enclosed or open types and have a variety of electrical connections. Form and color of the lens and method of attaching the lens holder present a great variety of choice. Ap-

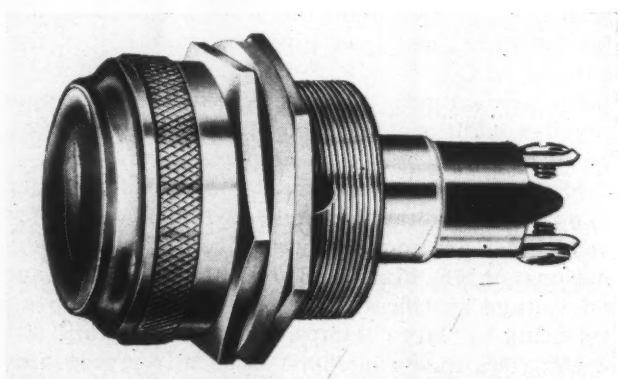


Fig. 4—Large-size enclosed pilot light with 1⅝-inch OD bushing. Suitable for C-7, S-6, and S-11 lamps, unit is used where high brightnesses are needed

pearance on front of panel depends on the finish of the lens holder which serves to frame the lens.

Open assemblies are simple in design and offer fewer choices. Such an open type pilot light, *Fig.* 3, has a lamp socket supported by an integral bracket which is secured to the back of a panel by a large nut threaded to the shank of the lens holder. The open assembly has the advantage of being tamperproof from the front of the panel, but it requires access to the rear of the panel for lamp replacement.

Enclosed pilot lights such as shown in *Figs.* 2, 4, 5, and 6 are generally preferred since they permit lamp replacement from the front of equipment and are made in a wide choice of optional features. Pilot-light fixtures of this type are usually designed with a tubular bushing which is externally threaded for fastening to panels. This bushing supports a lamp socket at the rear and a lens holder attaches to the bushing on the front of a panel. Such assemblies may be inserted in the panel from either side. If intended for installation from the front, the bushing has a flange which rests on the front and a nut and lockwasher secure the pilot-light assembly from the rear. If attachment is desired from the rear of a panel, a back nut is staked on permanently at a position appropriate to panel thickness and a round knurled nut tightened against the front serves to hold the unit.

Since enclosed assemblies are made to accommodate every type of pilot-light bulb shown in *Fig.* 1, it follows that every type of socket may be mounted in some suitable bushing with an inside diameter which provides sufficient clearance for the lamp bulb. Sockets must, of course, provide the necessary insulation protection for the applied lamp voltage and must be insulated from the bushing which may or may not be grounded. Socket connections are made by means of soldering terminals, *Figs.* 2 and 6, or binding screw terminals, *Figs.* 4 and 5.

A wide choice range is available in lens holders and lenses which make up the pilot-light cap. The cap is usually attached by a push-in friction type fitting, *Fig.* 5, or by internal or external screw threads. Also some push-in fittings have bayonet locking features. Lens holders provide an attractive frame for lenses and are chromium plated or furnished in other finishes to comply with final design requirements.

Lenses are made in many shapes and colors. Lens shape has an important effect on light distribution—concentrating it into an intense narrow beam or spreading it for wide-angle visibility. Usual lens shapes, whose names well describe them, are flat, convex, faceted, torpedo, dome, and stovepipe. For design situations where panels and fittings are large, large lens units can be specified to maintain proper scale relationships, *Fig.* 4. Lens material is either plastic or glass. Plastic is well suited for use over the relatively cooler neon and miniature lamps. Glass is preferred over lamps rated at 6 watts or greater or wherever high ambient temperatures prevail. All forms of lenses are made in red, green, amber, blue, translucent white, yellow, and clear colors. Blue and green lenses are not suitable for use over neon glow lamps as these light sources emit little light in these colors. Inside surfaces of some lenses are matted or frosted for diffusion of light from bright incandescent filaments. Outside surfaces of other lenses are frosted to prevent reflections of bright light sources that may be present in an area which might give the false impression of a pilot light being on when it was actually off.

In some applications of pilot lights, high brightnesses may be required for daytime indoor and outdoor use while low intensities may be needed in dimly lit or blacked out areas at night. For these environmental conditions, pilot-light assemblies designed with polaroid disks or a mechanical shutter arrangement should be employed, *Fig.* 6.

Two common special pilot-light features that the designer may need are water and oiltight constructions, and word disks. Watertight and oiltight installation with respect to the front of a panel is accomplished by utilizing screw caps which have a resilient washer back of the cap. The assembly of the lens into the cap is also special and includes a resilient washer seal.

When it is necessary to have a word, letter, number, or other symbol appear when the bulb in a pilot light is lit, a suitable disk is inserted in the assembly between the lens and the lens holder. Such disks may be etched metal, printed on parchment, or photographic reproductions (negative or positive).

As a guide, a listing of principal lamp and pilot-light assembly options is given in TABLE 2. This table may be used as a check list; however, not every combination of every option is available.

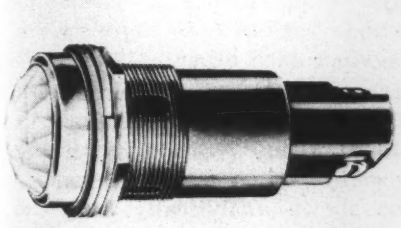


Fig. 5—Left—Enclosed pilot light with push-in friction-type lens cap. Holes in bushing provide proper ventilation for incandescent lamps

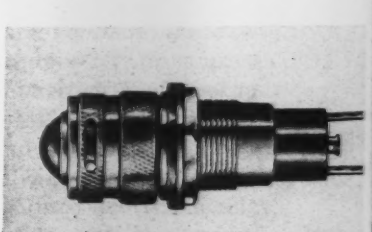
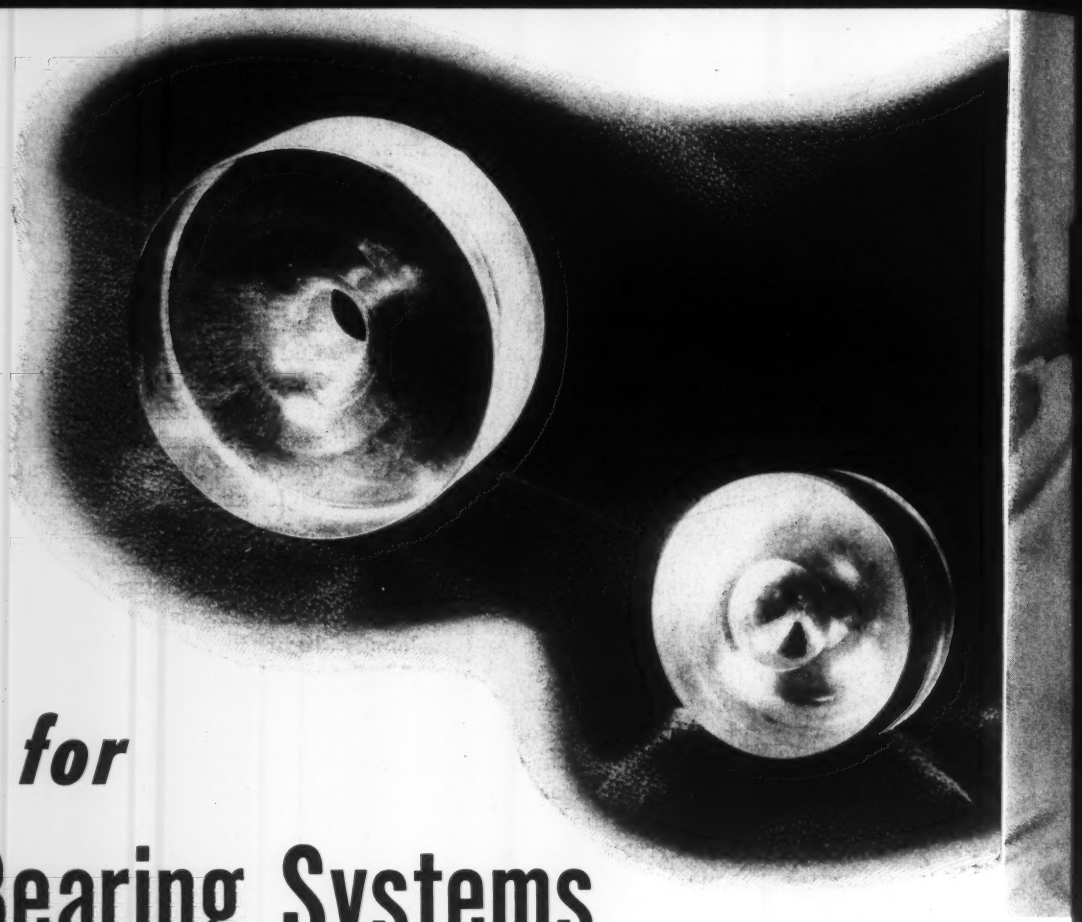


Fig. 6—Right—Unit made with either polaroid-disk or mechanical-shutter light control for use in both high and low brightness environments



Design Factors for Jewel Bearing Systems

By A. C. Lawson
Meter and Instrument Dept., General Electric Co., West Lynn, Mass.

MOVING systems of indicating instruments must be supported to allow the desired degree of rotation with a limited amount of friction and eccentricity between fixed and moving parts. The most widely used means for supporting any type of instrument moving system, be it a moving coil, iron vane, or moving magnet, is that of a jewel and conical-pivot or cylindrical-shaft construction. The shaft or conical pivots are usually rigidly attached to the moving system and rotate between two jewel bearings. Such construction is also being increasingly applied in miniaturized devices of many sorts. This article will describe differences of application of the two most common types of instrument jewel bearing systems and will discuss the design considerations of each.

Types Of Bearing Systems: The two types of bearings to which this discussion will be limited are the vee-jewel and the ringstone, *Fig.* 1.

Vee-jewels are used extensively in electric indicating instruments in which bearing friction torque must be kept to an absolute minimum in order that instrument accuracy will always be within specified limits. For true indication of the quantity that is being measured, the restoring torque on the moving system must either equal the electrical torque or differ from it by a constant amount. Since friction is not a constant quantity, the bearing friction must be held to a relatively low value for satisfactory instrument calibration. Commercial instruments utilizing the vee-jewel are small panel, switchboard, hook-on, portable and laboratory types, and exposure meters, some of which are shown in *Fig.* 2. *Fig.* 3 shows two typical moving systems supported by vee-jewels.

Vee-Jewel Design: If the weight of a moving system operating with the shaft vertical were supported by a theoretically sharp point, the contact area between pivot and jewel would be zero and therefore friction would be zero. An instrument such as this would be very short-lived, however, because shocks and vibration which it would experience in normal operation would soon flatten or distort the points. This would produce friction much greater than would have occurred had the pivot points been slightly rounded originally. For optimum design of the jewel and pivot contour, then, the two major requirements of *minimum friction* and *maximum resistance to deformation* must be balanced against each other.

In many applications of electric indicating instruments using the vee-jewel system, the instrument can be operated in any position—with the shaft vertical, horizontal, or in any intermediate position. It can be shown analytically that the maximum friction error exists when the shaft is horizontal. For this reason the remainder of the

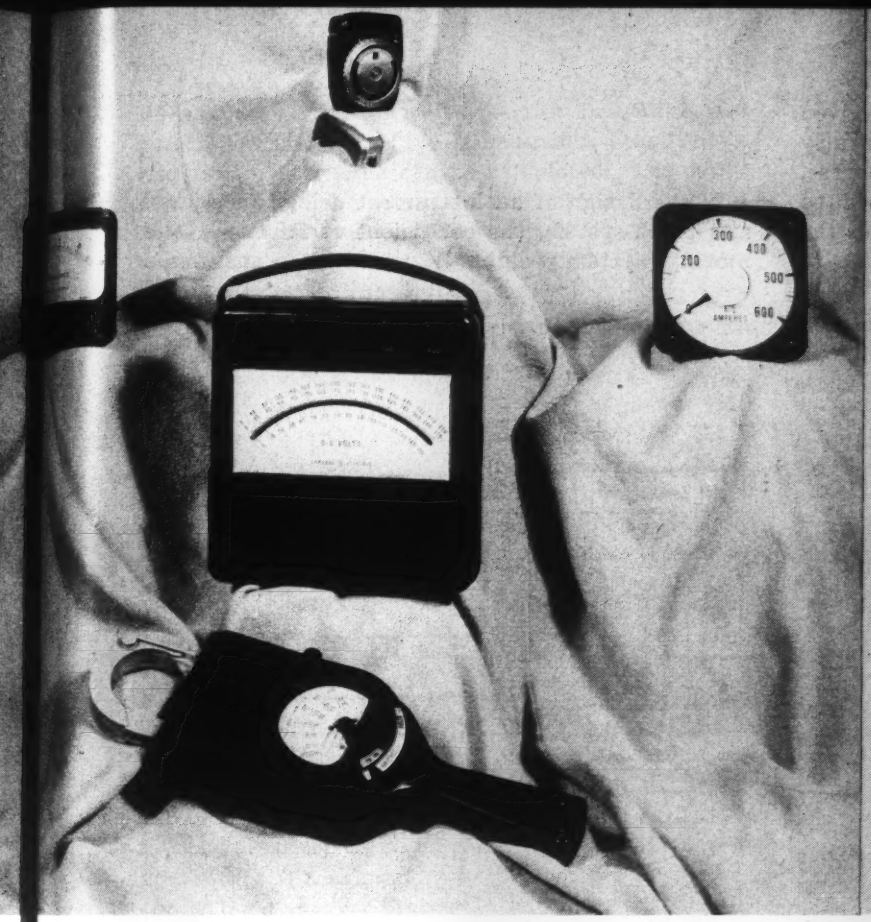


Fig. 1—Extreme left—Ringstone (left) and vee-jewel (right), the two most common types of bearings used in indicating instruments

Fig. 2—Left—Commercial instruments which use vee-jewel bearings are exposure meter, small panel, portable, switchboard, and hook-on types

discussion of vee-jewels will deal with horizontal friction only. In this position, as the moving system is actuated, friction causes the pivots to roll up the jewel wall until the wall becomes too steep to support rolling, and slipping occurs. This action is illustrated in *Fig.* 4*a*. The maximum friction torque resulting at this point is

$$T = \mu W R_p \cos \theta \quad \ldots\ldots (1)$$

where

R_p = Pivot radius, millimeters
T = Maximum horizontal friction torque, gram-millimeters
W = Weight of moving system, grams
μ = Coefficient of static friction between jewel and pivot
θ = Angle of pivot roll from neutral position to point on jewel at which slipping occurs, degrees

A more accurate expression for friction torque in a horizontal axis system has been derived by Nylander.[1] It involves another important design consideration—end-play of the moving system. The equation is

$$T = \mu W R_p \cos \tan^{-1} \frac{\mu}{\cos \sin^{-1} \left(1 - \frac{P_r}{R_j - R_p} \right)} \quad \ldots (2)$$

where

P_r = End play with the pivot contacting the spherical surface of the jewel, millimeters
R_j = Jewel radius, millimeters

Equation 2 is shown graphically in *Fig.* 5 which, for particular values of R_p, W, μ and R_j, shows how end-play affects friction torque. Two interesting observations can be made from this graph:

1. At end-plays of 0.001-inch and greater and a coefficient of friction of 0.10 or less, the friction torque is practically independent of jewel radius.
2. With the end-play reduced below 0.001-inch, an appreciable decrease in friction torque can be attained even with a relatively large coefficient of friction.

However, *Figs.* 4*b*, 4*c*, and 6 illustrate that the normal force at the contact area between jewel and pivot increases rapidly as end-play is decreased below 0.001-inch. It is seen, then, that minimum end-play cannot be the only criterion in reducing friction because high wedging forces accompany small end-play. If this wedging force is not kept within certain limits, serious pivot deformation can occur resulting in increased friction. A series of experiments conducted by Stott[2] showed that for an included pivot cone angle above 30 degrees the maximum allowable stress increases with cone angle. In addition, the rate of increase of bearing pressure with decrease in pivot radius depends upon the weight of moving system, *Fig.* 7.

[1] References are tabulated at end of article.

Equations 1 and 2 indicate that for a given bearing system the friction torque varies linearly with moving system weight, provided, of course, the bearing surfaces are clean and polished so that μ does not vary with load. In most cases, the rolling angle θ is small and Equation 1 reduces to

$$T = \mu W R_p \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

In the design of an instrument using a vee-jewel and pivot system, the coefficient of friction μ and moving system weight W known, the maximum

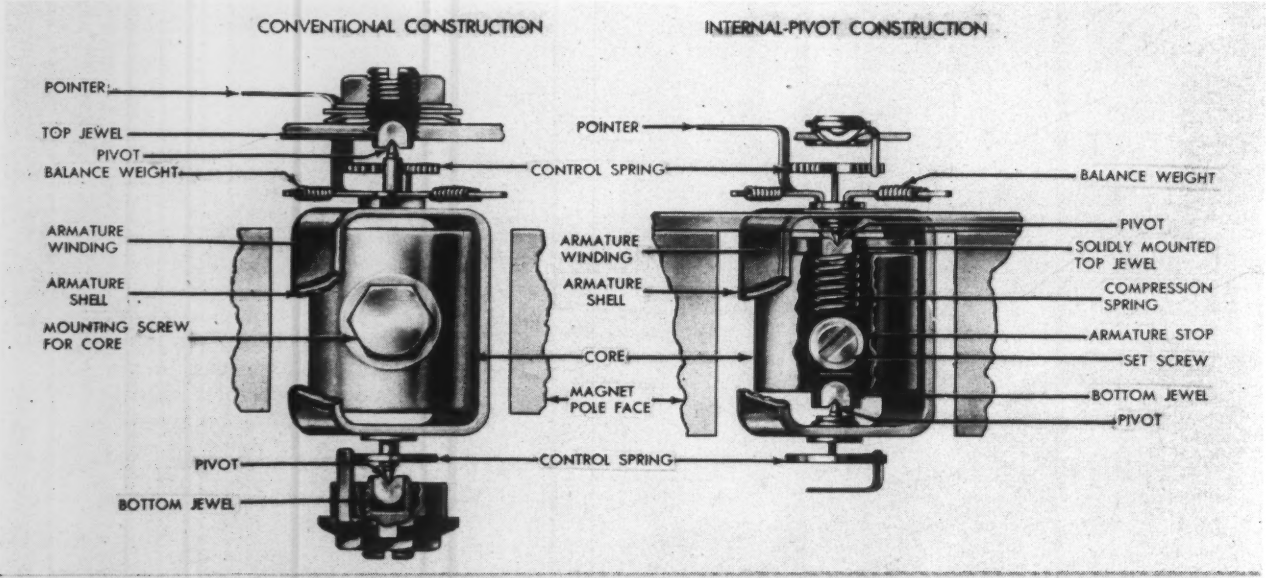


Fig. 3—Above—Typical small panel instrument elements showing moving system supported by vee-jewels and conical pivots

Fig. 4—Right—As moving system deflects as at *a*, pivot rolls up jewel wall until equilibrium is reached between rolling and slipping. Sections at *b* and *c* show how decrease in end-play, P_r causes increased normal contact force, W (cos θ/cos α)

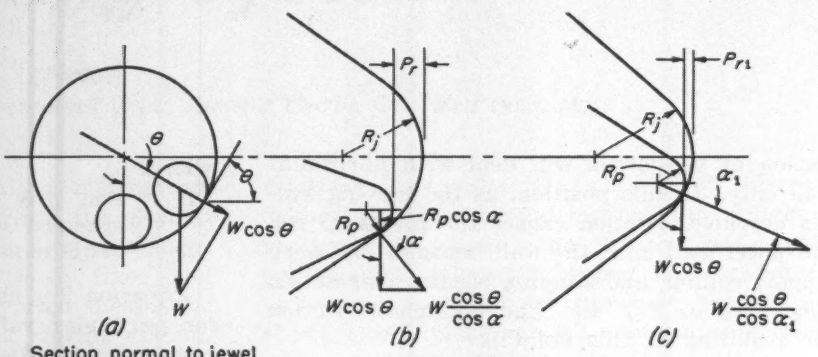


Fig. 5—Effect of end-play at constant values of μ and jewel radius. Moving system weight = 0.5 gram, pivot radius = 0.001 inch

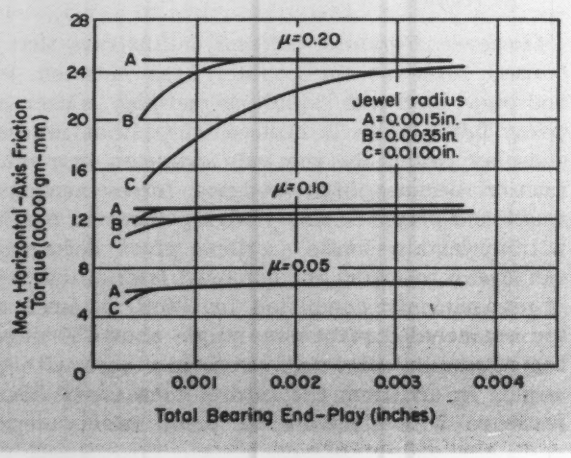
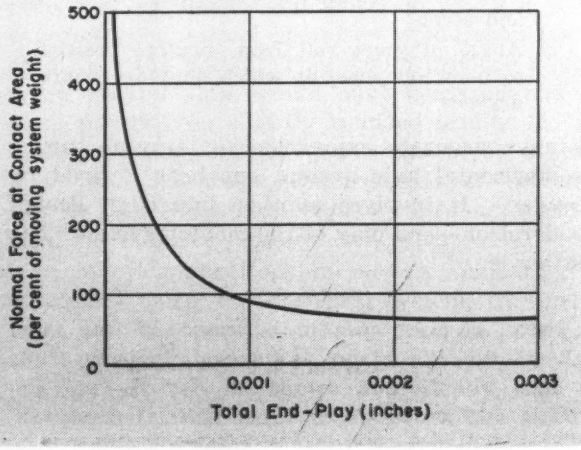


Fig. 6—Effect of end-play on normal force at bearing contact. Pivot radius = 0.001-inch, jewel radius = 0.0035-inch, and jewel cone angle = 80 degrees



allowable friction torque is usually known, (it depends primarily on the instrument sensitivity) and the pivot radius can be calculated. The jewel radius is made a maximum consistent with holding the eccentricity of the moving system within allowable limits and the contact stress within the elastic limits of the materials used.

Shock-Resistant Jewel Mountings: In certain instrument applications shock forces sometimes produce stresses in the jewel and pivot which would exceed the maximum allowable stresses if the jewel were mounted rigidly. The most common method for protecting the bearing system against such forces is that of mounting the jewel on a helical spring. In the majority of applications, this construction is perfectly satisfactory. For conditions of extreme shock and vibration, however, a recent development using sponge rubber has been proved superior because of its damping characteristics. As an example, one small panel instrument design, to meet an extremely stringent military specification, must withstand severe amplitudes and frequencies of vibration, tumbling in a steel barrel, and nine shock blows ranging from 1200 to 2000 ft-lb. The acceleration present when such shocks are applied is in the order of 1000*g*.

The basic design approach was essentially that of protecting the most vulnerable part of the instrument, the moving system. This was accomplished by cushioning each jewel with a small piece of sponge rubber.

The internal portion of the jewel screw is so designed that shock forces applied in any direction will move the jewel away from the pivot, *Fig.* 8. The jewel moves due to its own inertia rather than from armature acceleration force directed through the pivot. When the shock force is along the axis of the pivot, the jewel moves as a result of the blow. The pivot is restrained to a travel of 0.010-inch by a shoulder on the pivot support. The action of the soft sponge rubber is to damp the jewel motion severely, thereby preventing it from rebounding onto the pivot. Shock forces applied perpendicular to the axis tend to tip the jewels, allowing the pivot to strike the jewel on the periphery of its cone rather than the tip. The armature is restrained to a travel of 0.010-inch in this direction also.

Ringstone and Endstone Bearing Systems: A moving system using ringstone jewel bearings has higher friction torque than a comparable vee-jewel system because of the larger contact surface between pivot and jewel Some types of electric instruments can tolerate higher friction torque, however. Ringstones can therefore be used to advantage in producing much more sturdy bearing systems. For the same weight of moving system, the one supported by ringstones has a much lower bearing pressure than the vee-jewel.

Ringstones are used in preference to vee-jewels under the following conditions:

1. When bearing friction is negligible compared with the active electrical torque or with other friction or error-producing torques. An example is a recording instrument in which the moving system drives a pen across a chart. Here, the friction of pen on paper far exceeds the friction present in the bear-

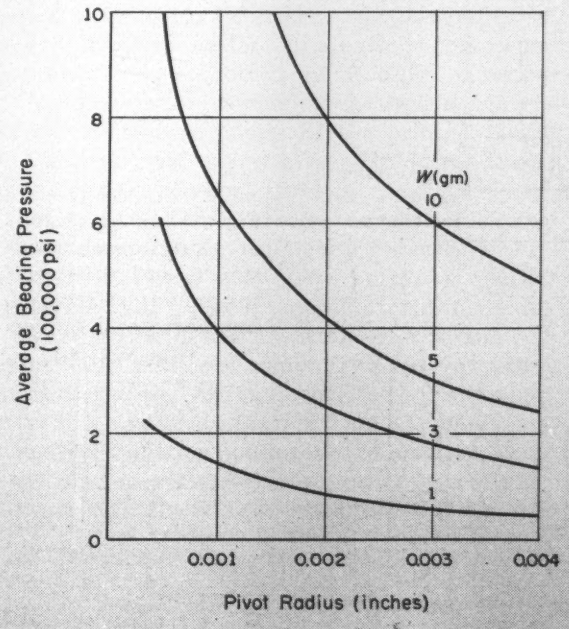


Fig. 7—Left—Average vertical shaft bearing pressure over contact area for various weights of moving system and pivot radius

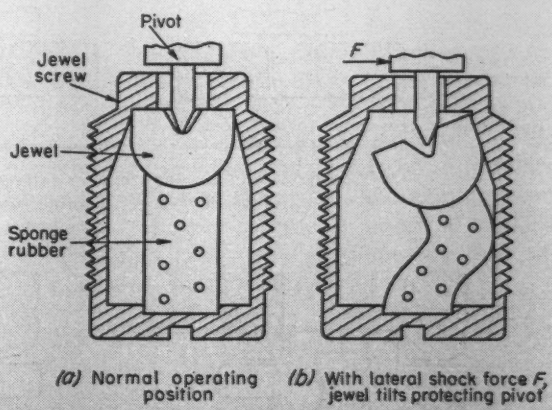


Fig. 8—Above—Shock-resistant jewel mount for electric instruments which must withstand severe shock and vibration. Pivot radius = 0.001-inch and jewel radius = 0.0035-inch

ings.

2. When the instrument in normal operation is subjected to continuous vibration, thereby reducing bearing friction torque. Aircraft instruments mounted on an airplane panel are an example of this application.
3. When the mechanical construction requires that the shaft extend through the bearing.
4. When side-play of the moving system must be extremely small.

There are various types and combinations of ringstone systems, as illustrated in *Fig.* 9. In instruments such as recorders where the shaft is always vertical, *Fig.* 9*a,* a ringstone-endstone combination is used for the bottom bearing, while the top bearing can be either a ringstone or vee-jewel. *Fig.* 9*b* shows horizontal shaft ringstone bearing systems. Certain applications require lower friction than can be obtained by the straight-hole ring-jewel. The olive-hole stone and the "bombe" type are refinements which give lower friction by virtue of the smaller pivot to jewel contact area. The bombe type is used in very special applications where minimum thrust as well as journal-bearing characteristics are required.

It is possible to hold the side-play of a moving system employing ringstones to a lower value than can be obtained with vee-jewels. *Fig.* 10 shows dimensions of a typical ring jewel. Note that the tolerances are given in ten-thousandths of an inch. The shaft can, of course, be made to the same tolerances so that side play can be limited to less than 0.001-inch.

Jewel Materials: Jewels of various materials, such as glass, sapphire, synthetic spinel, titanium oxide, beryllium copper, brass, etc., have been tried and tested. Depending upon the moving system weight, it has been determined that borosilicate glass and sapphire afford the optimum in initial friction, resistance to impact, and long life.[3]

In recent years, glass has become a substitute for sapphire in some vee-jewel applications, particularly small panel instruments. As a result of an extensive development program during the war years, when the accessibility of sapphire jewels from Switzerland was uncertain, glass was substituted for sapphire in vee-jewel applications where the total moving system weight is less than 0.75-gram.

The 0.75-gram value for glass vee-jewels has been empirically derived for rigidly mounted jewels and results from an exhaustive series of comparative tests on impact and shock resistance of glass versus sapphire. Of course, this moving system weight limitation can be exceeded if the jewel is shock-mounted.

Pivot Materials: The most common pivot material for use with vee-jewels is high carbon tool steel in the form of ground and polished drill rod. After hardening to a minimum Knoop hardness of 690, the pivot tip radius is generally put on by tumbling. Since in ordinary usage the pivot may be subjected to very high tensile, compressive, and impact forces, the microstructure of the hardened pivot is

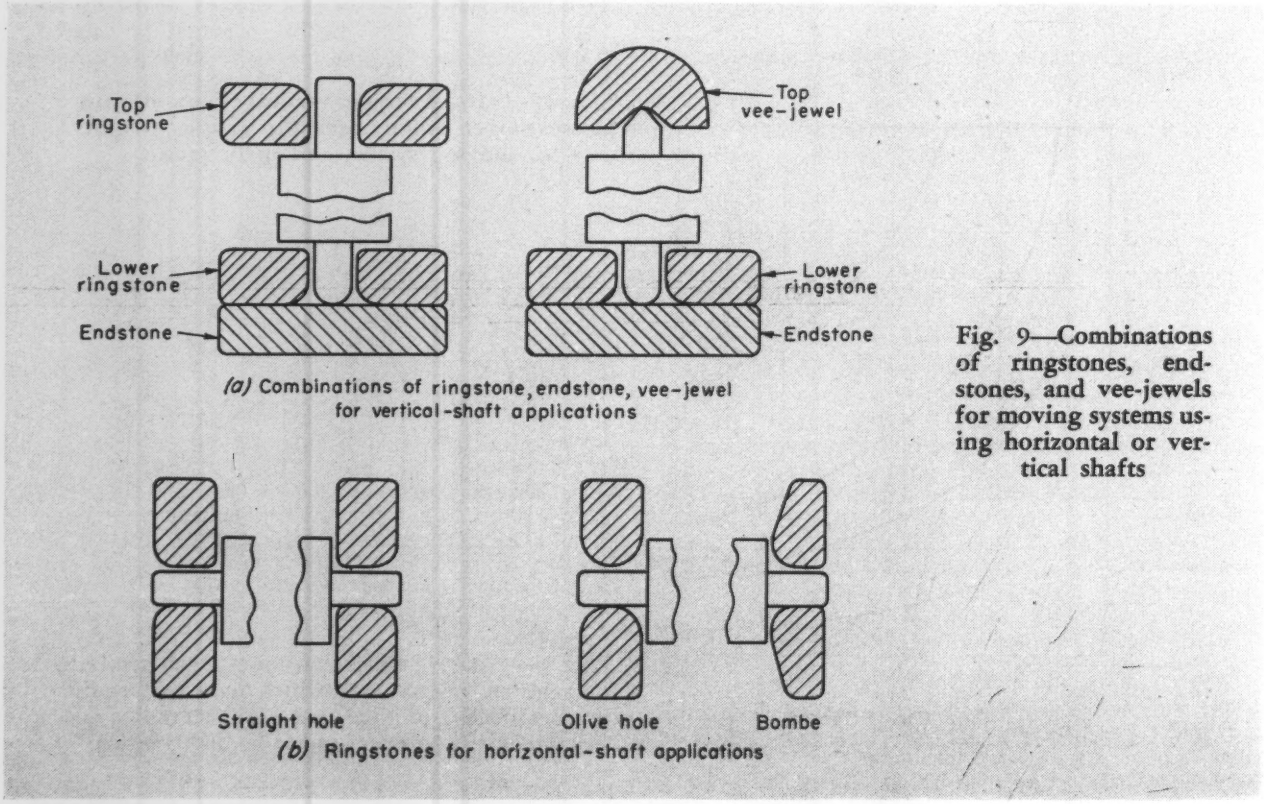


Fig. 9—Combinations of ringstones, endstones, and vee-jewels for moving systems using horizontal or vertical shafts

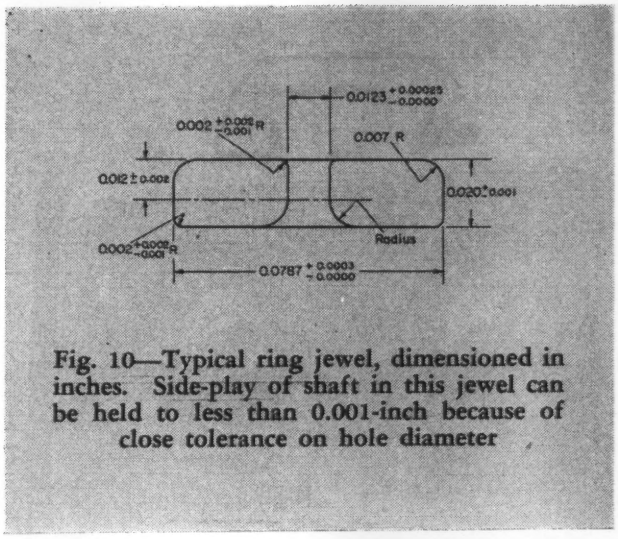


Fig. 10—Typical ring jewel, dimensioned in inches. Side-play of shaft in this jewel can be held to less than 0.001-inch because of close tolerance on hole diameter

closely controlled.

Some vee-jewel applications require nonmagnetic pivots to reduce the errors produced by magnetic hysteresis. In such cases monel metal, stainless steel, or tantalum shanks with osmium tips are used, the osmium giving a hardness comparable to the high carbon steel. Pivots of 92½ per cent tantalum, 7½ per cent tungsten are also used for nonmagnetic qualities.

Shafts for use in conjunction with ring jewels are cobalt-tungsten, monel metal, stainless steel, beryllium copper, tantalum, or high carbon steel.

For all pivot applications the material must be highly polished, and free of surface scratches or flaws for minimum friction and longest life.

Summary: Most electric indicating instruments in use today have a jewel-pivot bearing system. In applications where minimum friction consistent with safe loading is the prime factor, vee-jewels and conical pivots are used. When extremely low moving system friction torque can be sacrificed in favor of higher strength or mechanical construction advantage, ringstones are used.

REFERENCES

1. A. L. Nylander—"Instrument Bearing Friction," *General Electric Review*, July, 1946.
2. V. Stott—"Pivots and Jewels in Instruments and Meters," *Collected Researches of National Physical Laboratory*, Vol. 24, Paper No. 1, 1931.
3. F. K. McCune and J. H. Goss—"A New Jewel for Indicating Instrument," *AIEE Trans.*, Vol. 61. 1942.

Printing Process Cuts Drawing Reproduction Costs

RECENT experience at the Portsmouth Naval Shipyard seems to indicate that reproduction of drawings by printing processes rather than more usual methods such as blueprinting, may offer real economies and other advantages to companies requiring more than a few reproductions of single drawings. Faced with the task of providing as many as 9000 individual blueprints per month for procurement purposes, the Shipyard, early in 1953, conducted a study to determine the possibility of reducing blueprint costs; eliminating time consuming operations involved in folding, marking and filing prints, and reducing storage space required by the reserve copies of the prints. Their study indicated that using offset lithographic reproduction would solve all three of these problems.

In the Multilith offset process adopted, all original drawings are photographically reduced to negatives of a standard size. The negative is then used to produce a paper or metallic printing plate from which copies of the drawing may be run off on a Multilith machine. A comparison of print costs, weight and required storage space for the previous and present methods is shown in TABLE 1.

An analysis of the operation from July, 1953, when the plan was adopted, through October, 1953, showed an actual saving of $13,563.40. An analysis of the operation, TABLE 2, shows total costs for the Multilith method over this period and the estimated costs for a comparable number of blueprints and the attendant operations. Other improvements include reduction of administrative procurement lead time and accessibility of filed drawings. Firms supplying material covered by the drawings have been unanimously favorable to the plan and complimentary.

Table 1

	Blueprint	Multilith
Reproduction cost per print, $	0.38	0.073
Storage space per print, sq ft	9½	1¾
Weight per 100 copies, lb	14.06	2

Table 2

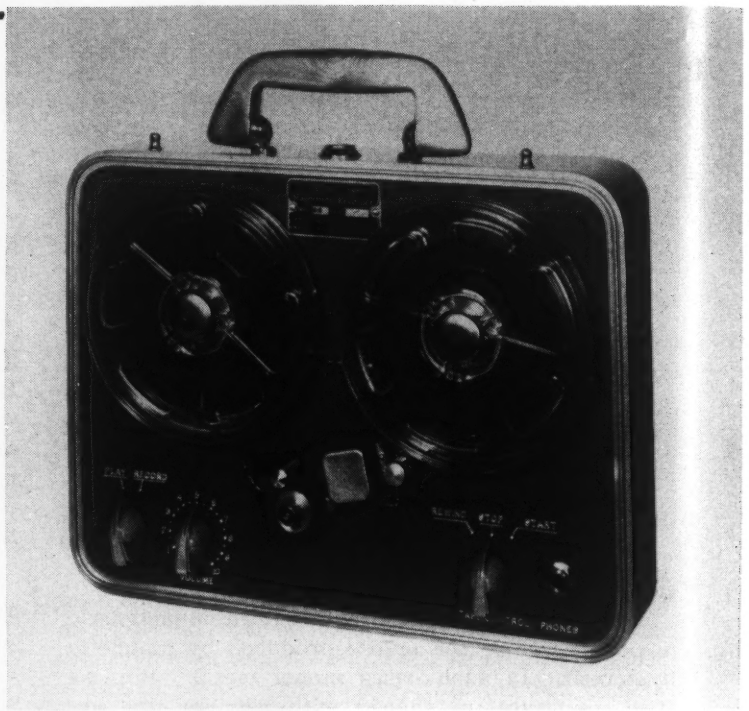
Former Method	
36,200 blueprints at $0.38	$13,756.00
Folding, marking, mailing, filing operations for 36,200 print:	
1600 man-hours at $1.75	2,800.00
Total Cost	$16,556.00
Present Method	
36,200 Multilith prints at $0.073	$2,642.60
Folding, marking, mailing, filing operations for 36,200 prints:	
200 man-hours at $1.75	350.00
Total Cost	$2,992.60

Abstracted from an article in the February, 1954, *Bureau of Ships Journal*.

Correction

In the article "Power Screws," November, Page 128, reference is made to the point of interference of an Acme screw thread in terms of the tangent of an angle on Page 132. The expression is tan $a = \tan \phi / \tan \theta$; this should read tan $a = \tan \theta / \tan \phi$.

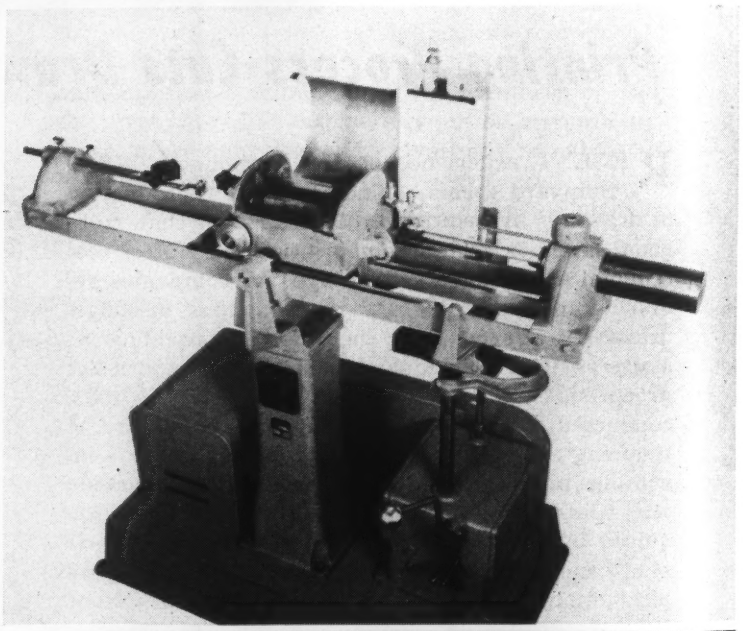
Portable Tape Recorder



BATTERY operated, the portable Magnemite magnetic tape recorder weighs only 8 pounds. A flyball governor-controlled electric motor gives constant speed during the full life of the batteries, and a built-in indicator shows when motor batteries should be replaced. Rewind is also electric, and takes less than 2 minutes. The motor is shielded and has a built-in noise suppressor to assure freedom from "hash." Construction is weathertight, since the case is of anodized aluminum alloy with tongue-and-groove extuded aluminum edges with a built-in neoprene gasket seal. The Amplifier Corp. of America unit will operate continuously on one set of dry batteries for 25 hours; total recording time is 4 hours with a 600-foot roll of ¼-inch tape on a 5-inch reel at 15/16-inch per second.

CONTEMPORARY DESIGN

Tire Cord Tester



MINIATURE ball bearings provide accuracy and minimize penholder torsional friction in the Scott Testers Inc. Incline-Plane Tensilgraph. In the test, a specimen of tire cord is attached between grips at the left end of the machine and a carriage running on tracks. As the tracks are tilted, weight of the carriage, which is loaded with removable weights, loads the specimen at a constant rate as the tracks are inclined. Elongation is recorded directly on a chart by an attached pen as the carriage moves down the plane. When the specimen breaks, the carriage rolls free until it strikes a bumper at the right end of the machine.

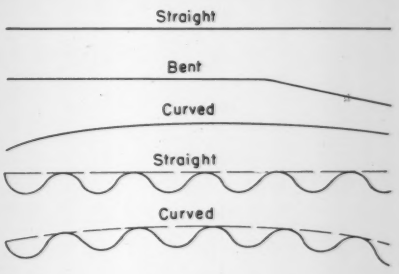
Penholder is mounted on a square pen bar, and weight-loaded to provide pressure against the paper. To provide maximum shock resistance in the penholder assembly, and to minimize wobble parallel to the pen bar axis, diameter of the bearing shaft at the end of the pen bar must be made as large as possible. However, lighter pen movement was considered desirable, obtained by minimizing size of the aluminum penholder casting which means using ball bearings with the smallest possible OD. The apparent paradox was solved by using superlight Miniature Precision bearings with extra-thin walls; the $\frac{5}{16}$-inch bore is $\frac{1}{8}$-inch larger than that of standard radial bearing with the same OD.

A NEW EXPRESSION "Geometrical Tolerances" appears in the draft of a proposed revision of Engineering Drawing Practice issued for comment by the British Standards Institution in 1952. The U.S. Department of Defense, Office of Standardization, included a section on "Positional and Other Geometrical Tolerancing" in Mil-Std-8A, 5 June 1953.

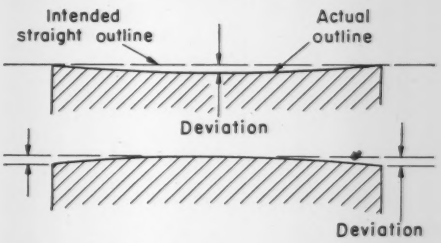
ASA Subcommittee Y14.5, of which the author is a member, in preparing a section for a new American Drafting Standards Manual, has been considering "geometrical tolerances" for the past two years. It is hoped that this short discussion of the subject will interest designers and stimulate discussion. The editors will be happy to forward readers' comments to the committee

By Allan H. Candee
Gear Consultant
Rochester, N. Y.

Specifying ACCURACY OF FORM for machine parts



Forms of Lines



Deviation of Actual Line from Intended Straight Line

TOLERANCES on size and distance have long been a regular part of drawing practice; but tolerances on form, direction, and position have been specified less frequently. Since all measurements of distances and angles depend on geometrical relations, it does not seem quite satisfactory to call only the second group "geometrical tolerances." Most common machining operations, however, produce surfaces that are plane, cylindrical, or conical, and it is both convenient and practical to adopt such forms in designing manufactured parts. Thus there are flat plates, straight bars, round pins, round holes, and so on almost without end. Accuracy in form, direction, and position is often essential and may need to be specified. For instance, the closeness of contact between two machined plane surfaces depends on the accuracy with which they approach the intended form, and the overall accuracy of an assembled machine depends on the accuracy of its parts.

In geometry a straight line, a plane, a right circular cylinder are *imaginary* and always perfect in form. We have learned to think about them readily. The forms shown and the dimensions given as information on a drawing are also imaginary, and are perfect according to the ideas of the designer. Anyone trained to read the drawing will correctly receive the designer's intention. Tolerances on measurable distances are readily understood. Tolerances on form, however, are deviations from zero in relation to some imaginary reference, and unless such tolerances can be interpreted in a way that applies to practical methods of measurement, there will be disagreement and confusion. This

article discusses some of the difficulties.

It is becoming more and more necessary to specify *how accurate* the forms and surfaces must be. This requires giving attention to a number of elementary geometrical characteristics which can be logically grouped:

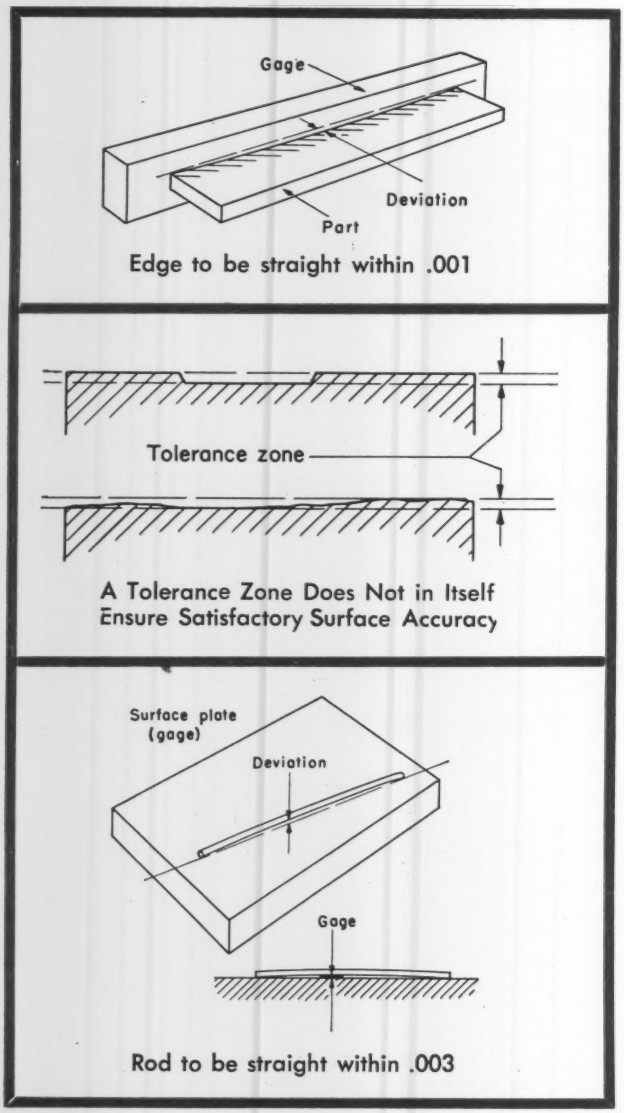
Form	Direction	Position
straight	at an angle	concentric with
flat	parallel to	in the position shown
round	square with	etc.

Unless we think about these characteristics as applied to actual parts, it is easy to go too far into the realm of imaginative and abstract ideas. Therefore it will help to stay on practical ground if we keep in mind concrete instances like:

Form	Direction	Position
a straight shaft	a surface at *X* degrees	a gear concentric with its shaft
a flat bar	a surface parallel to *A*	a hole in the intended position
a round hole	a surface square with *A*	

Taking as an example a cylindrical hole, here is a list of the kinds of inaccuracy which are recognized and measured by gages that may be used for close inspection:

1. Tapered (not parallel)
2. Barrel shape (not straight)
3. Bell shape (not straight)
4. Bent (not straight)
5. Elliptical (not round)
6. Lobed (not round)



For a hole in which a precision spindle is to be assembled there are no less than six ways in which the highest attainable accuracy is required: it must be straight, parallel (of constant diameter), and round, and it must be correct in diameter, direction, and position. Each of these individual characteristics must be measured, and if each is toleranced we arrive at a very complex specification. This extreme example suggests that there may be a question about how far specified tolerances can take the place of good and competent workmanship.

In every case the accuracy of a given surface can be considered on the basis of two simple ideas: the *intended* surface which was in the mind of the designer, and the *actual* surface that exists on the finished part. Then we can say that the tolerance is the allowed amount of difference between the actual surface and the intended surface.

A flat piece may be laid on a surface plate (which is a kind of gage) and differences or deviations observed, and perhaps measured by "feelers" of known thickness. The same thing may be done with a flat bar or round pin to see if it is straight. For precision the gage may be an optical flat.

In this way of thinking, and doing, there are only two surfaces in the picture, the actual surface and the intended surface. Another way of thinking about accuracy is based on the idea of *tolerance zones,* the zone being the space between two imaginary surfaces, usually parallel planes, and there are *three* surfaces to think about. Or the tolerance zone may be an imaginary, small cylinder in space within which an imaginary line must lie. There is nothing in such a picture for us to touch or see, and although the idea may be logical it is a complicated matter to discuss with those who measure manufactured parts by the customary methods.

To show how complicated the ideas about accuracy may become, here are statements and attempts at definitions of the simple designation *straight,* quoted from several sources:

1. "The surface, or the axis of the feature must lie within the tolerance zones shown in these diagrams." (From the British Standards Institution, 1952) Under *Straightness* a diagram shows a round pin bent and with a slightly curved center line contained in the tolerance zone which is a "cylinder 0.003 diam."
2. "Straightness—The tolerance zone governing the straightness of an axis or axial plane is the diameter or width of the tolerance zone within which the relevant axis or axial plane must lie." (From a U. S. Military Standard, 1953) Diagrams that illustrate the interpretation of the symbol and tolerance for *straightness* show a curved line designated as "axis" and a curved line designated as "axial plane."

In geometry and mechanics an axis of revolution

and an axis of symmetry are always *straight lines.* It does not seem right to ignore this when interpreting information on engineering drawings. Certainly if the common definitions are to be disregarded an explanation ought to be offered.

3. "Flatness (Straightness)—Plane surfaces: A machined plane surface shall be flat with respect to its reference plane within the limits specified in Table 1." (From "standard practice instructions" of a manufacturing organization, prepared early in 1952) There is a separate description of "reference plane." The wording "flat with respect to" can be questioned.
4. "Straightness is the characteristic of an edge or surface of less than $\frac{1}{16}$-in. width, which coincides with a reference edge or surface plate." (From an "engineering bulletin," 1952) An illustration shows a slightly curved strip lying on a surface plate.

The two preceding examples show a practical way of thinking. Next are examples of what happens when an attempt is made to be technically exact and more specific. They are by members of the subcommittee on drafting standards:

5. (a) "Straightness: must be straight within 0.XXX." "Deviations may be visualized with respect to an imaginary straight line. The direction of this line is established by the two highest points of the actual edge or line; or, for a slightly convex edge, by one high point and the intention of the designer as shown on the drawing."
   (b) "Straightness is a condition resulting when a line, edge, or element of a surface has everywhere the same direction. . . . the deviation from a straight line touching the edge or element at two or more points is not to exceed the tolerance."

The present author has tried his hand (pen) at this sort of thing, and arrived at the following:

(c) "straight within 0.001-inch states the permissible deviation of points on the outline of a straight object in a plane section, from an imaginary straight reference line that is in the direction of the line connecting the two end points of the actual outline and lies entirely either outside or inside the actual outline, and touches it at one or more points."

This may be correct but it has become too technical. Something shorter and easier is needed. *Straight line* in a general dictionary is a line "not bent or curved." And "curved" is defined "not straight." At first glance this seems unsatisfactory; but it should be remembered that in geometry "any precise definition of the most elementary terms is impossible for the reason that there are no terms more elementary with which to define them. Such terms include point, straight line, surface and angle." (From the *National Encyclopedia*) We should not undertake to give a definition of *straight* for drawing practice, but we might explain what the tolerance on a straight object means. We can say, for instance, that the specification "straight within 0.002-inch" means that the part considered is not to be bent or curved by more than 0.002-inch.

ACCURACY OF FORM

It can be shown that the idea of a tolerance zone does not cover the possibilities of inaccuracy as completely as those who have introduced it appear to suppose it does. If for a flat surface we imagine a tolerance zone between two parallel planes 0.002-inch apart, it is also possible to imagine that the actual surface has steps, plateaus, flat-bottomed valleys, slopes, or other irregularities—all occurring within the 0.002-inch tolerance zone. It is therefore necessary to include another idea in the specification and have it understood to begin with that the surface must be *smooth.*

Some of the other characteristics, like *round* and *concentric,* lead to even more discussion—and argument—than occurs with *straight.*

So far the geometrical designations have been discussed as simple, direct descriptions. In several publications, however, the characteristics have been named as straightness, flatness, roundness, angularity, parallelism, perpendicularity, concentricity, symmetry, and true position. These are all imaginary abstract conceptions that seem unnecessarily difficult to talk about in designing and drafting, and in machining and measuring manufactured parts. Some of us prefer simple and ordinary expressions like the notes that have been put on drawings in the past:

Straight within 0.002
Flat within 0.002
Round within 0.001
At angle shown within 0.001
Parallel to *A* within 0.002
Square with *A* within 0.001
Concentric with *A* within 0.001
Runout not to exceed 0.002
Eccentricity not to exceed 0.001
Within 0.001 of true position

In every case the tolerance states the allowed deviation of the actual surface, line or point from the intended surface, line or point.

Instead of individual tolerancing a general note may be sufficient and save a lot of detail. It might be: "Accuracy of finished surfaces 0.XXX unless otherwise specified." It is being found very difficult to decide how individual tolerancing should be treated in a drafting manual. The subject reaches far beyond drawing information and is involved with manufacturing procedures.

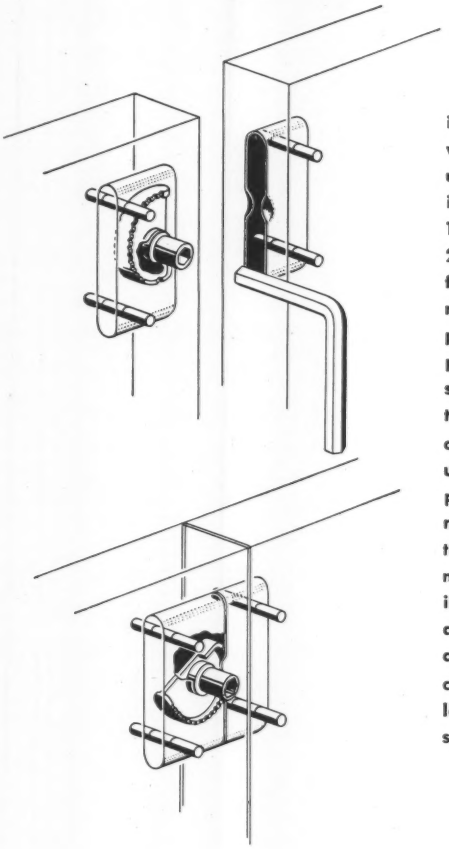
In some plants where experience and knowledge exist, long-established practices enable parts to be produced satisfactorily without individual tolerances on form and surfaces. With the new emphasis on specifying such tolerances over and above the results of good mechanical workmanship, there is danger that costs of drawings and of manufacture will be increased unnecessarily. This calls for experience and judgment on the part of both designers and production personnel. In the standardization of drawing practice it must be kept in mind that manufacturing procedures are constantly changing and that conditions are almost never the same in different plants.

DESIGN DETAILS

Practical solutions for design problems with standard components

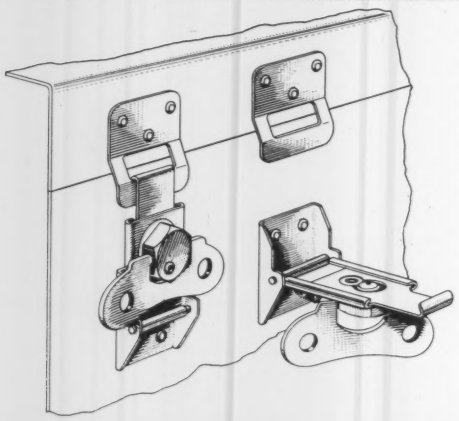
Panel Latches

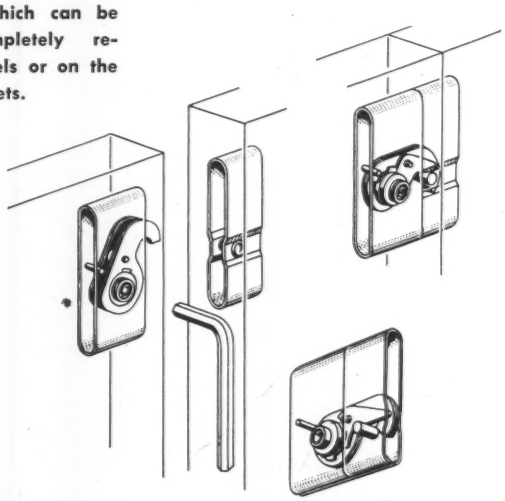
Panel latches offer a wide range of practical usefulness where demountability is an important design consideration. Available types can be adapted to all types of materials in varying sizes and thicknesses to provide a high-strength sealed butt joint which is resistant to temperature, vibration and shock. Typical fastening possibilities are shown in the accompanying views which illustrate some standard positive-locking structural types manufactured by the Simmons Fastener Corp. Load capacities of these latches run up to as high as 7000 pounds in tension. All provide a high closure force to insure fluid-tight sealing, and effects of temperature or severe service are minimized by rugged constructions not employing springs or delicate mechanical parts.



Rotating cam latch utilizes a tapered cam to provide positive locking and unlocking action. Load ratings for this type run up to 1400 pounds in tension and 2000 pounds in shear. The fastener assembly can be recessed completely into panels to eliminate any exposed parts or can be side-mounted for use on thin sheets. Several methods of installation can be used, such as screws and pins, and the mounting need not extend through the panel, particularly if minimum heat transfer from inner to outer surfaces is desired. In case of misalignment, or if panel closure is obstructed, the latch can be locked in a semiopen position.

High-load latch employs a double-acting take-up mechanism to obtain high mechanical advantage and heavy closure pressures. Load capacity of this type is 7000 pounds. In operation, a draw-to locking action is provided by an off-center cam which actuates the latch hook. Full open and closed positions are assured by a built-in trigger; the trigger mechanism is operated through projections on the cam and is positioned by contact with a female engaging pin to assure a positive lock. Accidental unlocking or loosening is prevented by the design which can be mounted completely recessed in panels or on the surface on sheets.



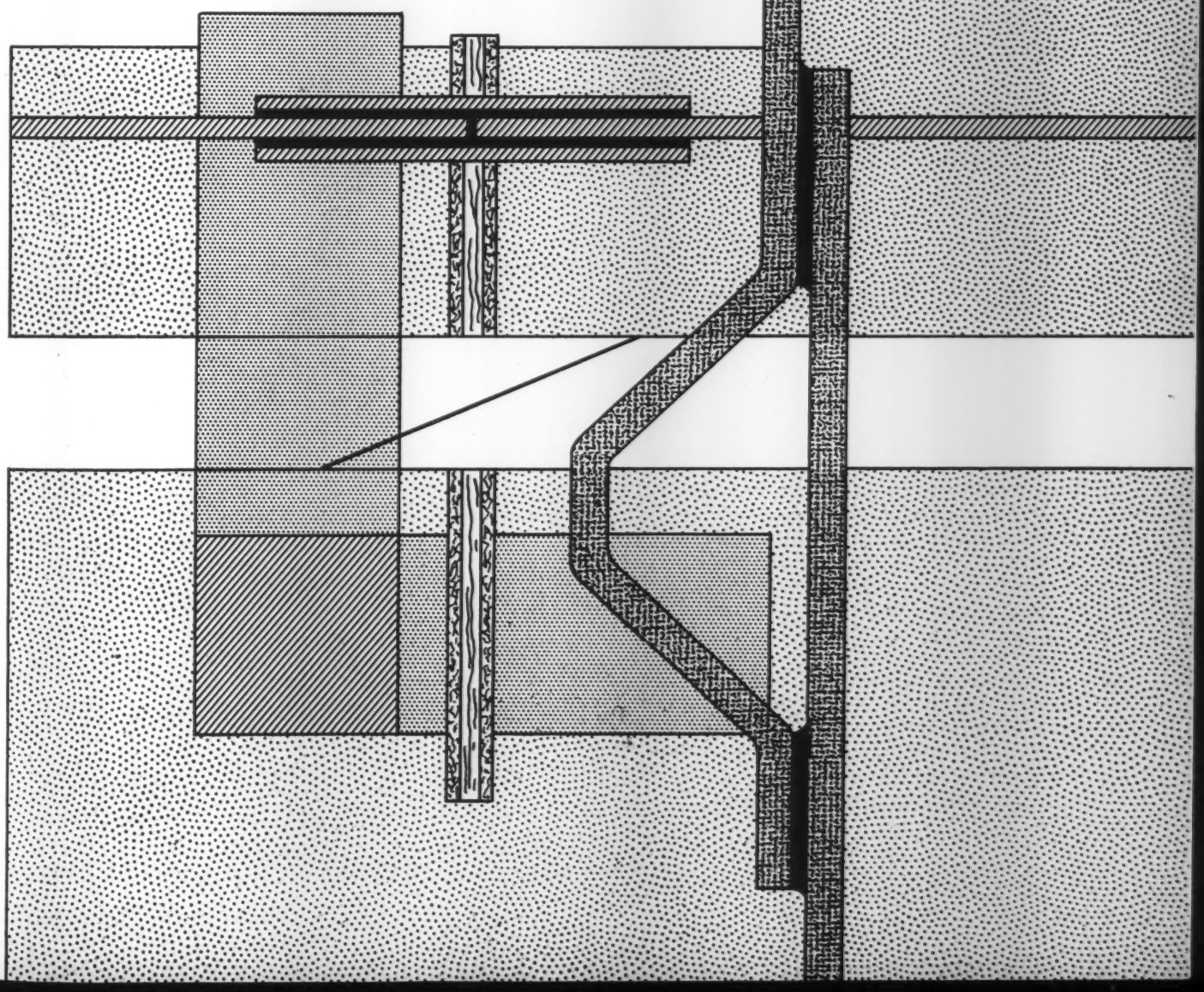


Engaging tongue latch for exterior mounting is particularly suited for adverse weather environments and especially low temperature conditions. Medium-duty type shown provides up to 450 pound pull-down pressure for preload and can carry tension loads up to 1000 pounds. Modifications of this type are available for pulldown pressures as low as 90 pounds or as high as 1500 pounds; tension load capacities of these assemblies vary from 300 to 4000 pounds, Locking or unlocking is accomplished by turning the wing-nut 90 or 180 degrees, depending on the latch type. Standard variations are also available with a bolt or screw head replacing the wing nut or in different engagement latch designs to meet varying application requirements.

Design Manual on

ADHESIVES

Fifteen months in preparation, this fundamental reference work summarizes current design practices and recommendations resulting from a thorough study across industry. The comprehensive discussion on characteristics, selection and use of adhesives is based on practical data and experience supplied by a wide cross section of adhesives users and manufacturers. Original material for the article was developed and prepared by G. W. Koehn, in charge of adhesives research and development for Armstrong Cork Co., as a manual for the Ordnance Corps, Dept. of the Army. The Ordnance manual will be published later this year.



DESIGN MANUAL

Types of Adhesives
Choosing an Adhesive
Bonding Methods
Joint Design

Photos, courtesy Timber Engineering Co.

ALL-WOOD TRUCK BODY developed as a complete adhesive-bonded assembly utilizing stressed-skin construction. The frame or skeleton is made of laminated veneers to form U-shaped beams which serve as floor and side supports. Side and floor panels are plywood, bonded to the frame to form the "stressed" skin. Mechanical joints between bottom and sides are not needed, and the result is a complete single unit developing exceptional strength per pound of weight. Wood parts are treated to resist fungus, decay, shrinkage or swelling. The adhesive—either resorcinol, phenol or melamine formaldehyde type—is completely waterproof.

DURING the past ten to fifteen years development of new adhesives with improved properties has proceeded at an expanding rate. Impetus to the development of new products has been supplied by the acceptance of adhesives as reliable means of attachment and the need for adhesives with better properties. The constant quest for new adhesives to perform under conditions ever-increasing in severity implies that they are satisfactory under less severe conditions, and there must be some

ON ADHESIVES

reasons for preference of adhesives over other means of attachment. What are these reasons?

Many examples can be cited where materials cannot be combined with one another through any means other than adhesives. It is difficult to imagine how a label could be applied to a bottle or can without an adhesive or an adhesive tape. Lamination of metal foil to paper or plastic films, installation of wall tile, assembly of metal skins on plastic cores for sandwich construction would all be impossible or economically unfeasible with anything but an adhesive. These are applications where adhesives reign alone and compete with no other method of attachment.

But what about metals? Metals have been fabricated successfully for many years with bolts, rivets, screws, and welds. However, adhesives, too, enter the picture with their own distinctive advantages. Assembly of heavy gage metal to thin sheet is difficult by welding, and other means of attachment are limited in strength by the bearing strength of the thinner sheet. Metals cannot be welded to nonmetals, nor is welding generally suited or widely practiced in combining dissimilar metals. Assemblies of this nature are adaptable to adhesives, and adhesives offer advantages. Bonded light-gage metals do not fail in bearing, but rather the full strength can be realized, and the presence of an adhesive film between dissimilar metals can minimize bimetallic corrosion.

Adhesive bonds are continuous bonds; that is, the entire bonded area is attached, minimizing stress concentration at points of attachment that may occur with rivets, spot welds and bolts. Even distribution of stress over the bonded area results in greater strength and rigidity in the assembly. This factor often allows reduction in thickness of material in the structure, elimination of stiffening mem-

Photo, courtesy Synthane Corp.

MATCHED INSULATING PROPERTIES and high-strength bonds are important in these seals, fabricated from laminated plastic and rubber combinations. The soft rubber on both sides forms an effective seal against leakage of oil-filled capacitors, while the thermosetting plastic center provides mechanical strength and a consistent hole size, thus making mass-production methods possible.

Table 1—Thermoplastic Rubber Adhesives (continued)

sistant, although some can sustain relatively low loads at 160 F. In many cases they may gain strength when exposed to 160 F, depending primarily on the resins used in compounding. Where strength requirements are at a very minimum, exposure to temperatures of 250 F generally has no degrading effect on the adhesive. The Buna-N's age very well, are water resistant, and resist mold growth. Bond strengths vary considerably with the compounding, from tacky, low-shear, high-peel-strength products to adhesives with high peel strength and shear strengths of the order of 2,000 psi, uncured. Similarly, products vary in their ability to sustain continuous stress without creeping. Adhesives which are better in this respect are limited to a maximum of about 100 psi.

Chemical resistance of Buna-N adhesives is of value in bonding materials which may exude plasticizer. For example, the Buna-N's are commonly used for bonding unsupported vinyl film, not only because bond strength is adequate, but also because softening action of the plasticizer which may exude from the film is resisted. For similar reasons, they are used for bonding rubbers which are compounded for low temperature flexibility, although they are not satisfactory with all rubbers of this type. Generally speaking, they bond well to most rubbers where strength requirements are not too high, but bond best to Buna-N stocks.

Most of the thermoplastic Buna-N adhesives are liquid products which may be applied by roller coater, brush or spray at solids contents from 15 to 40 per cent. Heavier products are used as sealers rather than adhesives. Shelf-life of the liquid products at room temperature may be from 3 months to more than 1 year.

Latex adhesives containing Buna-N rubber may be compounded with resins, plasticizers, thickeners and other modifying materials. General properties of latex films are similar to those of the solvent-laid films, except water resistance usually is not as good. Also, the heat resistance of the solvent adhesives is improved through the use of phenolic resins in the compound, and most latex adhesives do not contain phenolic resin. Although latex adhesives dry somewhat slower than solvent adhesives on impervious surfaces, they often dry faster on surfaces which absorb water. On such surfaces latex adhesive sometimes offer an advantage, in that the adhesive solids remain entirely on the surface, where solvent adhesives are often absorbed. Latex adhesives, as well as solvent adhesives, can be compounded to be nonstaining with vinyls. To obtain this nonstaining property to the maximum degree, other properties such as heat resistance sometimes must be sacrificed.

bers or reduction in size, which can result in overall weight and cost savings. Continuity of the bond and better stress distribution afforded by adhesives also contributes to superior fatigue properties under vibratory loads as compared to other methods of attachment. Most of the adhesives suitable for bonding metal to metal have some elongation, which permits the transfer, distribution and absorption of stresses. In properly designed joints the metal often fatigues before the adhesive. Since the adhesive bond is continuous, a seal against the passage of liquids can be effected. Also, with the proper adhesive, continuity of the bond gives effective electrical insulation.

Adhesives do not break through or deform the surface to which they are applied, a property of special importance where a smooth surface is desirable. For example, on the airfoil surfaces of airplanes reduction in resistance to air flow can result in higher speeds. Also, sheets adhesively bonded do not require grinding or filling prior to finishing operations.

Assembly with adhesives may or may not offer cost advantages, depending on the size and nature of the part, and relative cost of other methods of fastening. Adhesives require no drilling of holes, as do rivets and bolts but, on the other hand, some adhesives require extensive jigs for application of heat and pressure. Some large assemblies have been bonded with substantial savings over riveting, even taking into consideration the high cost of tooling; however, small assemblies which can be set up for automatic spot welding may be more costly to bond.

There are also disadvantages to the use of adhesives. Some require heat and pressure for curing to establish the bond. Required jigs and fixtures may be expensive, making their construction impractical for a small number of parts. Adhesives may be susceptible to weather conditions, in some cases not bonding well at high humidity or at low temperatures. Many adhesives are of questionable durability when exposed to severe conditions, questionable because in most cases the background of many years experience is lacking. Apart from certain exceptions, adhesives are organic in nature, and consequently do not possess the stability of metals at higher temperatures.

Adhesives will find more and more use as time goes on. The designer should become acquainted with the advantages and limitations of adhesives, what to look for, and what to avoid. The purpose of this manual is to present such general information on adhesives.

TYPES OF ADHESIVES

The number of adhesives in commercial use at the present time is quite large. There is no entirely adequate single system of classification for these products. In the trade they generally are classified broadly in terms of end use as wallboard adhesives,

metal-to-metal adhesives, wood adhesives, general purpose adhesives, label pastes, etc. Such a system is inadequate for a broad discussion of adhesives since one adhesive may find use in several fields. The American Society for Testing Materials is attempting to classify adhesives on the basis of the temperature required for an adhesive to establish a good bond, such as cold-setting (below 68 F), room temperature setting (68 to 86 F), intermediate temperature setting (87 to 211 F), and hot-setting (above 212 F).

Another system which has been used in industry to some extent is based on the fact that an adhesive must be liquid at some point in the bonding operation to establish adhesion, and the classifications are based on the method used for establishing the bond or liquefying the adhesive. Typical groups would be pressure-sensitive adhesives, chemical-setting adhesives, heat-setting adhesives, and solvent-release adhesives.

Adhesives may also be classified broadly by chemical type, that is, the basic ingredient from which the adhesive is made. This system will be used in the following discussion. Since mechanical properties of adhesives seem to depend more on the thermosetting or thermoplastic nature of the bond, two major divisions can be made; TABLES 1 and 2 outline the characteristics of thermoplastic adhesives; TABLES 3 and 4 of thermosetting adhesives; and TABLE 5 of miscellaneous water-base adhesives.

Thermoplastic Rubber Adhesives: Adhesives containing rubber are among the most versatile industrial adhesives in use today. All the common types of rubbery polymers are used in adhesives, includ-

Terms Commonly Used with Adhesives*

Adherend: A body held to another body by an adhesive.

Adhesion: The state in which two surfaces are held together by interfacial forces which may consist of valence forces, interlocking action, or both.

Adhesive: Substance capable of holding materials together by surface attachment.

Binder: Component of an adhesive composition which is primarily responsible for the adhesive forces which hold two bodies together.

Blocking: Undesired adhesion between touching layers of a material, such as occurs under moderate pressure during storage or use.

Catalyst: Substance which markedly speeds up the cure of an adhesive when added in minor quantity as compared to the amounts of primary reactants.

Cohesion: State in which particles of a single substance (adhesive or adherend) are held together by valence forces.

Condensation: Chemical reaction in which two or more molecules combine with the separation of water or some other simple substance. If a polymer is formed, the process is called polycondensation.

Crazing: Fine cracks which may extend in a network on or under the surface of or through a layer of adhesive.

Cure: To change the physical properties of an adhesive by chemical reaction, which may be condensation, polymerization or vulcanization; usually accomplished by the action of heat and catalyst, alone or in combination, with or without pressure.

Delamination: Separation of layers in a laminate.

Extender: A substance, generally having some adhesive action, added to an adhesive to reduce the amount of primary binder required per unit area.

Faying surface: Surface of an object which comes in contact with another object to which it is fastened.

Filler: Relatively nonadhesive substance added to an adhesive to improve its working properties, premanence, strength or other qualities.

Gel: A semisolid system consisting of a network of solid aggregates in which a liquid is held.

Glue: Originally, a hard gelatin obtained from animal hides, tendons, cartilage, bones, etc., or adhesive prepared from this substance by heating with water. Synonymous with "adhesive" through general usage.

Gum: Colloidal substances, exuded by or prepared from plants, sticky when moist, composed of complex carbohydrates and organic acids, which are soluble or swell in water. Also loosely used to denote materials that exhibit gummy characteristics.

Hardener: Substance or mixture added to an adhesive to promote or control the curing reaction. Also a substance added to control hardness of the cured film.

Inhibitor: Substance which slows down chemical reaction. Sometimes used to prolong storage or working life.

Polymerization: Chemical reaction in which the molecules of a monomer are linked together to form large molecules whose molecular weight is a multiple of that of the original substance.

Resin: Any of a class of solid or semisolid organic products of natural or synthetic origin, generally of high molecular weight with no definite melting point. Generally water-insoluble and have little or no tendency to crystallize, although some are readily dispersible in water, and a few are readily crystallized.

Sizing: Material, or process of applying material, used to fill pores on a surface and thus reduce absorption of a subsequently applied adhesive or otherwise modify properties of the adherend to improve adhesion.

Spread: Quantity of adhesive per unit joint area applied to an adherend. Single spread refers to application to only one adherend of a joint; double spread to both adherends.

Tack: Stickiness of an adhesive, usually measured as pull resistance to effect division without failure or deformation in the adherend or interface while the adhesive still exhibits viscous or plastic flow.

Tack, dry: Property of certain adhesives, particularly nonvulcanizing rubber adhesives, to adhere on contact to themselves at a stage in evaporation of volatile constituents, even though they seem dry to the touch.

Tack Range: Period of time in which an adhesive will remain in the tacky-dry condition after application under specified conditions of temperature and humidity.

Thermoplastic: Capable of being repeatedly softened by heat and hardened by cooling.

Thermosetting: Having the property of undergoing a chemical reaction by the action of heat, catalysts, ultraviolet light, etc., leading to a relatively infusible state.

Vulcanization: Chemical reaction in which the physical properties of a rubber are changed in the direction of decreased plastic flow, less surface tackiness, and increased tensile strength.

Working life: Period of time during which an adhesive, after mixing with catalyst, solvent or other compounding ingredients, remains suitable for use.

* Adapted from ASTM standard D907-49T.

Table 2—Thermoplastic Resin, Oleoresin and Asphalt Adhesives

THERMOPLASTIC RESIN ADHESIVES

Cellulose Derivatives

Cellulose nitrate adhesives are not only the oldest in point of service, but also are the most versatile, as witness the well-known common household cement. Nitrocellulose adhesives adhere well, forming a tough bond to a variety of materials such as glass, leather, metals, cloth, and some plastics. They are water-resistant and age fairly well, but discolor in sunlight. Having high viscosity and good tack, they develop strength rapidly with tough films being formed even with some residual solvent present. The films are flammable. One of the important uses is bonding of thermoplastics.

Cellulose acetate adhesives are more heat-resistant than nitrocellulose products and exhibit better aging, but are not as moisture-resistant. Principal use is bonding cellulose-acetate plastics and cellulose-acetate photographic film.

Ethyl cellulose adhesives are available as solvent solutions or as hot melts, varying in properties from soft and tacky to quite tough, strong products. Good bonds are formed to porous materials as paper and cloth, but adhesion of the tougher products is not too good to metals or glass. Main use has been with paper. Films are resistant to oil, mold, and fungus, but water resistance is mediocre.

Vinyls

Polyvinyl acetate adhesives are the most versatile of those containing vinyl resins. They are available as solvent solutions or as emulsions, either plasticized or unplasticized. In some cases they contain fillers and pigments.

Solvent adhesives generally have rather low solids and high viscosity. They can be roller-coated, brushed, or applied with caulking guns, depending on viscosity, but generally do not spray very well. Good adhesion may be obtained to metals, glass, wood, and porous material such as leather and cloth. The water-white transparent films are quite light-stable. Although only moderately resistant to water and dissolved by most solvents, they have excellent resistance to grease, oils and gasoline. Vinyl acetate adhesives retain the last traces of solvent tenaciously. Maximum bond strengths are obtained by baking the films at elevated temperatures prior to assembly. Although bond strengths of several thousand psi may be realized, the thermoplastic nature of the resin adhesives leads to failure at loads substantially lower under conditions of continuous stress. Principal uses for the solvent adhesives include bonding of plastics, shoe manufacturing applications, and a combination of bonding and caulking translucent plastic assemblies.

Vinyl-acetate emulsions are particularly useful with porous materials such as wood and paper. With wood, they lose water rapidly and consequently set quickly, allowing pressure release in some cases as soon as 20 minutes after assembly. Wet tack of vinyl-acetate emulsion adhesives, combined with quick setting properties, make them quite useful in automatic labelling operations, case sealing, and continuous combining of metal foil and paper.

They are free from taste and odor, are resistant to oils and greases, mold growth, and acids. These properties make them valuable in the food packing industry. Although generally applied by roller coater, consistencies are available for brush or spray application. The adhesives are not "waterproof," but water resistance is adequate for most interior uses. The resins resist the passage of asphalt through the film, minimizing asphalt bleeding, a property of value in bonding leatherette or supported vinyl to asphalt-impregnated boards.

Polyvinyl alcohol adhesives are supplied as water solutions, usually extended with starch and sometimes with clay, for the bonding of porous materials such as paper and cloth. Water resistance is fair, generally adequate to prevent delamination of paper, and resistance to grease and oils is excellent. These adhesives are odorless and tasteless. They consequently find application in the packaging of food. They may be made fungus resistant. Although vinyl alcohol adhesives can be heat sealed, a measure of heat resistance can be compounded into the adhesives so they will stand the temperatures of the order of 150 F under low stress. They have been used in packaging for the armed services.

Vinyl-vinylidene resin adhesives are supplied as solutions in powerful solvents like methyl ethyl ketone. The dried films are tough and strong, transparent, colorless, resistant to hydrocarbon solvents, chlorinated solvents, greases and oils. The adhesives are used where excellent solvent and water resistance is required along with a transparent film. Bonds are good to textiles.

Vinyl butyral adhesives are made as solvent solutions of high viscosity and low solids content. They are water-white and transparent, light stable, and have excellent adhesion to glass. Water resistance is relatively poor, but humidity resistance is adequate for most applications. Vinyl butyral is used in the lamination of safety glass. Solutions of vinyl butyral find some application as pressure-sensitive adhesives where aging stability is important. Although vinyl-butyral adhesives bond well to a variety of materials, they are not widely used as industrial adhesives.

Acrylics

Acrylic resin adhesives are available in three forms: as solvent solutions, as emulsions, and as monomer-polymer mixtures to be set with catalysts. The acrylates are water-white and transparent, and remain so in service, showing good weathering and sunlight resistance. They may be obtained with film properties varying from soft, tacky resins to hard, tough, solid products. In the bonding of acrylic plastic sheets, bond strengths as strong as the plastic are obtained. Acrylic adhesives are especially useful in applications where transparency is necessary, as fabrication of plastic domes.

Miscellaneous Resins

Shellac has been used as an adhesive for many years, both as a hot melt and in alcohol solution. Fairly strong bonds are formed with porous materials, and shellac bonds to some metals. Water resistance is good, also resistance to oil and grease, and hydrocarbon solvents. Since shellac is thermoplastic, heat softens it. Shellac has been used in the

ing crude natural rubber, Buna-N, neoprene, GR-S, butyl, reclaim, and Thiokol. Liquid adhesives are made in a variety of solvents, in latex form or as water dispersions, with the rubber generally compounded with resin modifiers, plasticizers, and in some cases with fillers and vulcanizing agents. Rubbers differ from one another in properties such as oil resistance, strength, tack, and resistance to aging. Resin modifiers can impart various properties to the different rubbers, such as substantial differences in tack and tack range, heat resistance, strength or adhesion. And most rubbers are soluble in more than one solvent, thus influencing the drying rate, tack range, and rate of strength development. Other types of compounding ingredients likewise influence the properties of rubber adhesives. As expected, with such latitude in compounding, rubber adhesives differ widely in properties. The main differences for various types of rubber are shown in TABLE 1.

Thermoplastic Resin Adhesives: Adhesives in this

electrical industry, and as a primer over difficult-to-wet metals prior to application of other adhesives, as gasket cements, for bonding cork assemblies, etc.

Manila gum adhesives have been made with alcohol solvent and clay fillers. At troweling consistency these have been useful as so-called "waterproof" adhesives for floor coverings. Both manila gum and shellac are inherently tougher than hard synthetic resins which are alcohol-soluble. They release solvent quickly, which is sometimes an advantage where quick strength development is desirable.

Rosin has served as the base for adhesives both in hot melt and solution form. For such a purpose it is usually plasticized. Aging properties of rosin in thin films are not particularly good because the resin is subject to oxidation. Soft, sticky rosin adhesives have found use in temporary holding applications.

Limed rosin, filled to heavy consistency and usually plasticized, has been used as a mastic for installation of acoustical tile and wallboard. Adhesives with heavy consistency have strength enough to hold relatively light loads immediately after application of the adhesive to the work. Heat resistance of limed rosin adhesives is substantially better than that of rosin cements. Aging properties of the adhesives are fair but there is a tendency to brittleness. They have fairly good water, oil, and grease resistance, but are saponified by alkali.

Cumarone-indene resins have been of value as the base for solvent adhesives with good alkali resistance. Toluol or xylol are used as the solvent, and fillers are incorporated to give a troweling consistency. Bonds strengths are of a relatively low order, but the films are quite hard and tough, and show good adhesion to concrete, wood, felt and cloth. The adhesives possess good water resistance, but soften at elevated temperatures.

Polyamide resins have not been used extensively in the adhesives field. Principal application is for heat-sealing paper coatings. Hot melts are characterized by good flexibility and toughness, and excellent resistance to grease and oils. An advantage of the polyamides lies in their ability to heat seal at temperatures of the order of 150 F, yet to be relatively nonblocking at room temperature.

OLEORESIN ADHESIVES

Oleoresinous adhesives are made from vegetable oils such as linseed oil, fish oil, tall oil, and chinawood oil in combination with resins such as limed rosin, rosin, phenolic resins and alkyd resins. The usual oleoresin adhesive requires a minimum amount of solvent, as the combination of oil and resin is in itself a viscous liquid. With suitable fillers, soft mastic compounds can be made. Since mastics are of heavy consistency, they generally are applied by trowel, knife, caulking gun or spatula.

Oleoresin adhesives have excellent tack and immediate strength, due primarily to consistency, and readily wet almost any surface. Although fair water resistance is demonstrated, they may be saponified by alkali, and are softened by most common solvents. Being compounded to remain soft and plastic, they have relatively low bond strengths but are adequate for such applications as installation of acoustical tiles and wallboard. With adequate film thickness, aging properties are quite good, films remaining pliable and plastic for many years. Continuous exposure to elevated temperatures causes stiffening and embrittlement, effects not ordinarily observed at room temperatures. Low temperatures have little or no effect on the set adhesive, pliability remaining at —50 F. The adhesives are not subject to damage from freezing, and bonds can be made at freezing temperatures or below. Apart from adhesive uses, such compounds are also useful for caulking purposes.

ASPHALT ADHESIVES

Asphalt is another versatile binder finding extensive use in adhesives. Water emlusions, solvent solutions or cut-backs, and hot melts are all widely used. Asphalt is basically a liquid, albeit a viscous liquid, which tends to cold flow even at room temperature. Asphalt adhesives are satisfactory only under conditions of little or no stress. Bond strengths of asphalt adhesives are relatively low, and fall off rapidly as temperature is raised. Asphalt adhesives become brittle at about 20 to 30 F, depending on the type and hardness of asphalt. Heat resistance, and the amount of flow that may be expected at moderately elevated temperatures, depends also on the particular asphalt and on the compounding of the adhesive. Flow at elevated temperatures also depends on the type of adhesive, whether hot melt or cut-back, or emulsion. Clay emulsion when dried may not flow at a temperature of 250 F, whereas a cut-back or hot melt usually does.

Outstanding characteristics of asphalt adhesives are water and alkali resistance. Thick films are also quite impermeable to moisture vapor. With adequate film thickness, asphalts age well, although products differ considerably in resistance to outdoor weathering. Oils, greases, and common solvents soften all asphalt products. The adhesives are used in many applications where strength of bond is considered secondary to resistance to water, alkali or acid. In some applications asphalt products probably should be considered as coatings rather than as adhesives.

Asphalt adhesives are inherently tacky, varying widely in this property from soft and sticky to hard films which, however, become readily tacky at slightly elevated temperatures. Adhesion is quite good and they bond to a wide variety of materials, such as concrete, glass, metal, paper and felt. Hot melts have been used for the erection of corkboard insulation, the lamination of paper and foil, and the lamination of treated papers and felts, among a variety of other uses. Emulsions have been used as binders in roads, for installation of asphalt tile, for the lamination of felt, and for bonding waterproof packages.

group, TABLE 2, have thermoplastic resin, of which there are a number of types, as their main constituent. These may be dissolved in solvent or emulsified in water. They may also be modified with plasticizers and in some cases with fillers and reinforcers. They all have the property of heat-softening, and are not changed chemically during bonding. Thermoplastic resins differ in this respect from thermosetting resins, TABLE 3, which are not affected by heat to the same degree and which do change chemically in establishing a bond.

Resin adhesives may be handled in two ways to establish a bond: (1) by coating both surfaces, partially drying, and allowing the remaining solvent to escape after the parts are pressed together, or (2) by allowing the coated parts to dry thoroughly before assembly and combining under heat and pressure. The former method is successful with porous materials such as cloth, paper, and leather, bonding either to themselves or to a nonporous surface. Solvent release is difficult when bonding two impervious materials, particularly

Table 3—Thermosetting Resin Adhesives

Urea-Formaldehyde

Urea-formaldehyde adhesives are extensively used for bonding wood in both plywood manufacture and assembly gluing. Supplied as two-part products consisting of resin and hardening agent to be mixed at time of use, they are available as liquids with separate hardener or as spray-dried powders with hardener incorporated which must be mixed with water at the time of use. Hardeners or setting agents contain reactive paraform and acidic catalyst which, once added to the resin, start chemical reactions. These limit pot life to one to 24 hours, depending on the specific adhesive formulation. Similar reaction starts when water is added to the dry powder type. The chemical reaction setting the adhesive can take place at room temperature or may be accelerated by baking at temperatures up to 200 F.

Bonded assemblies develop enough strength for ordinary handling in from 6 to 12 hours. Fair strength is developed in 24 hours. Approximately 6 to 10 days are required for maximum strength and water resistance. Assembly must be done under pressure, of the order of 150 to 200 psi, depending on wood species, shape of the parts, etc. Conventional urea adhesives yield bond strengths great enough to fail wood when glue lines from 2 to 7 mils thickness are used. They are not suitable for gap filling, where glue lines of 15 or 20 mils are required, as for example in some assembly work where parts do not fit perfectly. The so-called "craze-resistant" resins, which may contain furfural alcohol or similar chemicals as a modifier, work well in thick glue lines, showing good strength and good strength retention under service conditions.

Urea resins are nonstaining and light colored, making them suitable for use with light woods and thin veneers. Resistance to cold water is good, although the adhesive will not stand boiling water. They are not too satisfactory for service under conditions of high temperature and high humidity, or high temperature alone. Maximum service temperature is about 140 F. The ureas are not as durable as hot pressed phenolics, melamines, or resorcins, but are satisfactory for all but extreme service conditions. For many uses the ureas are extended with flour. In most cases they are filled to lower cost, but in some cases improvement in properties also results from filler. Excessive extension with flour can reduce water resistance.

Melamine

Melamine-formaldehyde resins are used for bonding wood where good durability is required. Melamines require pressing temperatures from 240 to 280 F. They cannot be cured at a substantially lower temperature without the addition of acidic setting agents. Hot-pressed melamine resins are equivalent in water resistance and durability to hot-pressed phenolic resins or resorcins, and the adhesives will resist boiling water. Bonds as strong as the wood are obtained. Melamine resins are compatible with urea resins and combinations are available which retain most of the desirable properties of the melamine at lower cost. The adhesives are light colored.

Acid-Catalyzed Phenolic

Liquid phenolic resins may be cured at room temperature, or through the use of heat up to 250 F, by the addition of acid hardeners. Acidity of adhesives of this type must be rigidly controlled, as excess acidity may result in damage to the wood. They have good water resistance and excellent color for phenolic resins. Primarily used as wood adhesives, they have also been used for bonding metal to wood, where the metal is first primed, usually with a vinyl-modified phenolic or a rubber-resin adhesive suitable for bonding metal to metal. Acid-catalyzed phenolics are unique among phenolic adhesives in their relative freedom from arcing in high frequency. Their use in wood gluing has expanded for this reason.

Resorcinol and Phenol-Resorcinol

Resorcinol and resorcinol-phenol adhesives are supplied as liquid resins to which formaldehyde or formaldehyde-containing hardener is added at time of use to form mixes which set at room temperature and above. Shelf stability of the liquid resin is excellent. Adhesives are supplied in alcohol-water solution at a viscosity suitable for hand spreading or machine spreading. Pot life after incorporation of the setting agent depends on temperature. At 75 F, pot life is about 3 hours. Chemical reaction starts as soon as the components are mixed; mixing of large batches is difficult, and the mixed adhesive should be kept cool.

Bond strength equivalent to the strength of the wood may be achieved at room temperature, although parts should be allowed 24 hours before machining or rough handling. Maximum chemical resistance generally is not developed in less than 6 days. Assemblies may be glued at 110 F with a press time of about 60 minutes, with the time diminishing as the temperature is increased. until 3-minute press time is adequate at 180 F. Durability of bonds with wood is equal to the durability of hot-pressed phenolics. The adhesives are unaffected by boiling water, mold and fungus, grease, oil, and most solvents. They are suitable for exterior use. For maximum durability in applications such as bonding oak timbers for ship construction, cure at moderately elevated temperatures is recommended.

Resorcinol and phenol-resorcinol adhesives bond to materials other than wood, including cellulose acetate, molded urea plastics, nylon, acrylic plastics laminated and molded phenolic plastics, etc. They also bond to porous materials such as paper, textiles, leather, and fiberboard. They do not bond to metal, but have been used for bonding wood to metal, with the metal suitably primed with metal-bonding adhesives. Straight resorcins are comparatively expensive; phenol-resorcins are lower in price. They are dark red in color, which makes them unsuitable for bonding thin veneer and light colored woods. Having some gap filling properties, they are suitable in glue line thicknesses of 7 to 15 mils, but are not as good in this respect as the "craze-resistant" ureas.

Phenolics

Phenol-formaldehyde resins and analogous products are of much importance in adhesives. They seem to have, at least in some forms, great adhesion for some of the materials which are difficult to adhere to, such as metals and glass. Widely used as modifiers for rubber to make thermoplastic rubber adhesives, they are also used in conjunction with thermoplastic resins or vulcanizing or curing rubbers in metal-to-metal adhesives. The phenolics are also used alone as adhesives. Several forms of resin are supplied: spray-dried powders to be dissolved in water; solutions in alcohol, acetone or water; and films. Powdered phenol-formaldehyde resins used in plywood manufacturing remain usable for about 6 months at room temperature. They are dissolved in water at time of use, remaining usable after mixing for about 24 hours. Curing is accomplished at temperature of the order of 280 F for several minutes. The resulting bond is stronger than wood. Durability is good, the adhesive being unaffected by boiling water, and it is resistant to mold and fungus. Such adhesives are suitable for exterior use. After the resins are polymerized with heat, they do not soften appreciably when reheated. Their properties are not appreciably affected by low temperatures.

Solvent solutions of phenolic resins filled with clay have been used as glass-to-metal adhesives for attaching metal bases to light bulbs and radio tubes. Such adhesives are cured at a temperature of about 300 F. These compounds are applied by extrusion or equivalent. Adhesives used for plywoods are generally applied by glue spreaders. The solution resins, when suitably cured, are also very strong and durable, and resistant to most chemicals. They are, however, somewhat brittle, tend to shatter on impact, and will not stand vibration very well.

Polyester

Unsaturated polyester resins in solution in monomeric styrene are liquid adhesives which may be converted to solid films without loss of volatile, as the solvent, styrene, copolymerizes with the polyester. Conversion from liquid to solid is accomplished with catalysts, usually peroxides, added at time of use. The cure may take place at room temperature or at 200-220 F. Containing no volatile material, the resins have the advantages of

setting thoroughly between impervious surfaces at low pressures, with relatively low shrinkage. Some of the resins do not cure in the presence of air, due to inhibition, but do cure when suitably covered and protected from air. The cured adhesives are resistant to moisture, chemicals, heat and weathering. Some have good electrical properties. Depending on the compound, films may be rubbery or hard, and properties may be varied between the extremes.

Tensile and shear strengths from several hundred to about 3000 psi may be realized, depending on the adhesive and adherends. Impact strengths are good. The polyesters bond to some metals and ceramics, but are particularly useful for bonding polyester laminates.

Epoxy

Relatively recent development of epoxy resin adhesives has furnished adhesives of considerable versatility and usefulness. Adhesives are supplied as resins with or without fillers, plasticizers, or other modifying ingredients, which are capable of reacting with hardening agents added either at the time of bonding or during the manufacture of the adhesive. Adhesives requiring the addition of a hardening agent at the time of bonding are, of course, supplied as two-part products. The bond may be established either through chemical reaction at room temperature or at elevated temperature, depending on the formulation. Those adhesives containing hardening agent incorporated during manufacture require heat to form the bond. The epoxys are supplied in several forms, as high-viscosity liquids, heavy pastes, powders, and sticks. Choice of the form of the adhesive depends on the method of application desired, on design of the joint, and method of cure required. Although the majority are essentially 100 per cent solids, containing no volatile solvents or volatile reaction products, low-viscosity liquid adhesives containing solvent have been found of value in special applications.

Liquid adhesives requiring addition of hardener have a pot life after mixing of about 30 minutes to 4 hours, depending on the formulation and temperature. They may set to a hard film in 15 hours, but generally 4 to 6 days setting time at room temperature is required for maximum strength and chemical resistance. Generally better cures are obtained by heating the joint for an hour at temperatures ranging from 150 to 200 F.

Adhesives in powder or stick form do not require incorporation of additional hardener, but in spite of their reactivity, storage life at room temperature is excellent. Since the adhesives can be stored at room temperature without reaction, it is obvious heat must be used to establish a bond. As with other chemical reactions, the time of reaction may be shortened as the temperature is increased. At 250 F approximately 24 hours curing time is required; at 320 F about 2 hours, dropping to about 5 minutes at 500 F. Although exposure of bonds for relatively long periods at temperatures of 350 F or below does not appreciably change the properties of the bonded joint, care must be taken at high curing temperatures not to allow overcuring to proceed any longer than is absolutely necessary.

Epoxy resin adhesives exhibit excellent wetting of metal surfaces. They bond to many materials including ferrous and nonferrous metals, ceramics, glass, wood and plastics. Excellent wetting characteristics are of importance where relatively tight joints must be bonded. Some epoxy resins form satisfactory bonds by application to the edge of the joint, flowing in through capillary action. Most manufacturers recommend joint thicknesses of 4 to 8 mils. Depending on formulation, shear strengths in the range of 1000 to 7000 psi have been realized, with the strength dependent on type of metal, thickness of metal, and depth of lap, as with other adhesives. The heat-hardening adhesives are considerably stronger than the room-temperature setting types. Although the adhesives are thermosetting, strengths fall off rather rapidly at temperatures above 212 F. Improvements in heat resistance are being made in some of the current developments. Low temperature properties are good, and impact strengths adequate. Chemical resistance depends on formulation, but generally may be considered adequate in benzene, alcohols, acetone, gasoline and oil. Although the adhesives lose strength on prolonged immersion in water, particularly at elevated temperatures, water resistance may also be considered satisfactory.

Particularly important advantages may be found in epoxy resin adhesives, in that bonds of considerable strength can be formed at room temperature and at little or no pressure. These factors are of major importance in bonding large areas requiring difficult tooling, and in the bonding of dissimilar materials where thermal coefficients become significant. Lack of volatile reaction products minimizes shrinkage, which is important in some adhesive uses. It allows the bonding of large areas without pressure build-up during cure, eliminating the necessity for breathing or venting such assemblies, which may be required when bonding with some other types of adhesives.

Principal applications of the epoxy adhesives include the bonding of aluminum skins on metal honeycomb for sandwich construction, cyclized rubber-to-metal assemblies, joining dissimilar materials such as aluminum and stainless in thin tube assemblies, and wood-to-metal and metal-to-glass seals.

Table 4—Rubber-Resin, Resin Blend and Thiokol Adhesives

RUBBER-RESIN ADHESIVES

Neoprene-Resin

Neoprene-resin adhesives have been designed specifically for bonding metal to metal for structural purposes. In many assemblies such adhesives have replaced other fastening methods such as riveting and spot welding. Liquid adhesives have been made in toluene or methyl ethyl ketone, or a combination of solvents, with a viscosity suitable for spray or brush application. They are also made in tape form, with an innerliner of glass cloth or nylon cloth.

Liquid adhesives are applied to the work, previously cleaned, to form a final cured bond thickness of 2 to 6 mils. Application to the work under high humidity conditions can result in inferior bonds, and controlled atmosphere is desirable for continuous production. The coated surfaces are then allowed to dry for solvent evaporation at room temperature, or may be baked up to 180 F to form a tack-free surface. Parts then may be assembled and cured at a temperature of 325 F, with pressures ranging from 50 to 500 psi. Curing times are in the range of 15 to 30 minutes after the adhesive joint has reached curing temperature. Since the adhesives are thermoset after the cure, they may be removed from the press or curing fixtures while still hot, and no cooling is necessary. Tape adhesives generally perform better if a liquid adhesive is first applied to the metal as a primer, with the tape placed between the faying surfaces after suitable drying of the primer, and the assembly then cured.

Cured films are relatively more rigid than thermoplastic adhesives, but not as rigid as well-cured phenolic resins. They have some elongation and elasticity so they deform slightly under stress. This

Table 4—Rubber-Resin, Resin Blend and Thiokol Adhesives (continued)

property is quite important, as it allows stress distribution within the joint, and gives the adhesives excellent fatigue resistance and impact strength. In fatigue, properly designed joints outlast the metal bonded. Shear strengths range from 3000 psi to 5000 psi, and tensile strengths are comparable.

Resistance to commonly encountered chemicals is excellent, the adhesives retaining useful strength levels after exposure to hot water, gasoline, and glycol. The bonds are usable over a wide temperature range from —70 to 180 F, although strengths at elevated temperatures are substantially lower than at room temperature. Strengths decrease about 50 per cent at 180 F. Resistance to creep and cold flow enables the adhesives to sustain relatively high continuous loads for long periods of time. This property is of much importance in bonding metal assemblies for structural purposes. Good bonds are formed with a variety of metals such as aluminum, magnesium, steel and stainless steel. Some compounds are relatively poor on copper, zinc and chromium. Satisfactory adhesion also is obtained to plastic laminates, wood, and a variety of other materials that will stand the curing temperatures. In bonding wood to metal, differences in thermal coefficients may cause distortion of the bonded part, or even bond failure, on cooling. Neoprene-resin adhesives have been found valuable as primers on the metal which, after curing open faced, may then be cold-glued with phenolic or resorcin adhesives to the wood. This procedure minimizes distortion and stress.

Buna-N-Resin

Buna-N-resin adhesives are available in liquid and tape forms. The liquid adhesives may be sprayed, brushed, roll-coated, or extruded. Tapes are free films, without fabric innerliners. Liquid adhesives require drying after application, drying relatively tack-free, and must be cured with heat and pressure. Although an adequate cure can be obtained at 325 F, in about 20 minutes, better strengths at elevated temperatures are obtained if the adhesives are cured at higher temperatures. The free films must also be cured under heat and pressure, with pressure requirements of 50 to 250 psi, depending on the assembly.

High bond strengths are obtained, with tensile strengths in the range of 4000 to 8000 psi, and shear strengths in the 3000 to 4000 psi range. Good impact strength and fatigue properties, and resistance to cold flow and creep, are typical of the rigid Buna-N products. Some of the adhesives are relatively brittle at —70 F, as evidenced by reduced impact strength and lower shear strength. Others are satisfactory. On the other hand, strengths at elevated temperatures are superior, and the compounds have good heat stability compared to some other adhesives suitable for bonding metal. They may be used in continuous service at 250 F, with intermittent exposure of short duration at modest stress to temperatures as high as 500 or 600 F. Principal applications for the thermosetting Buna-N adhesives involve high temperatures, such as the bonding of brake linings to brake shoes, clutch facings, and the attachment of grinding stones to metal holders.

Other types of thermosetting rubber-resin adhesives are used for bonding rubber to a variety of adherends. Although rubber adhesives used for bonding rubber to metal during vulcanization in some cases do not contain resin, usually some resin is present to aid adhesion. Bond strengths are generally good, heat strengths adequate, and the adhesives are generally serviceable in the applications used. They all require curing with heat and pressure, except some two-part adhesives which can vulcanize at room temperature. Those used for bonding unvulcanized rubber to metal cure during the vulcanization of the rubber, whereas those used for bonding vulcanized rubber to metal require separate curing.

RESIN BLENDS

Vinyl-Phenolic

Vinyl formal-phenolic resin adhesives have appeared in three forms: (1) as solutions which may be sprayed, brushed, or roll coated; (2) as tape with the adhesive coated on both sides of fabric; and (3) as separate liquid phenolic resin, with vinyl formal in powder form. In the latter case, liquid resin is applied to the work by spraying, brushing or dipping. Powder is sprinkled over the liquid and excess powder removed by blowing with air or by shaking it off. Liquid adhesives are air dried, and then baked at temperatures of 150 to 180 F for periods from 30 minutes to 24 hours prior to assembly, to minimize the amount of volatile material given off during the cure and, in some cases, to improve strength properties. The adhesives must be cured under pressure at temperatures ranging from 240 to 300 F. Shorter times are required at higher temperatures, ranging from an hour at 240 F to 15 minutes at 300 F. Curing temperatures as high as 500 F have been used successfully. Pressures required vary from 50 to 500 psi, depending on the area, closeness of fit, and type of assembly. Generally, optimum film thickness is in the range of 2 to 6 mils, although for applications such as the bonding of skins on honeycomb metal cores, where maximum stress distribution is desirable, substantially heavier films may be indicated.

Shear, tensile and impact strengths of phenolic-vinyl formal adhesives are quite good. Shear strengths are in the range of 3000 to 5000 psi on aluminum; tensile strengths are from 1000 to 4000 psi, depending on the metal bonded. Creep properties are also quite good. Elevated temperatures soften the adhesives somewhat and, of course, the adhesives creep more at elevated temperatures than at room temperatures. Formulation of the adhesive has considerable effect on strength and degree of thermoplasticity, and products vary from one another in these properties. Fatigue properties are typical of tough, thermosetting adhesives, with failure often found in the metal after several million cycles. The adhesives are durable, retaining adequate strength under exterior exposure, salt spray, high temperature and humidity. They are resistant to commonly encountered chemical deteriorating agents such as aromatic fuel, engine oil, hydraulic fluid and water. Typical uses for the adhesives are metal-to-metal applications for aircraft construction such as wing leading-edge assembly, sheet-stringer assembly, etc.; wood-to-metal and metal-to-metal sandwich constructions for aircraft; fastening metal skins on metal or paper honeycomb for sandwich purposes; metal-clad plywood, etc. The adhesives have also been used as primers on metal for subsequent cold gluing to wood with resorcin or phenolic adhesives.

Vinyl butyral-phenolic resin adhesives have many of the properties of the vinyl-formal modified phenolics, but are not quite as strong and tough. They, too, are supplied in several forms; (1) as free-film tape, (2) as coated paper tape, and (3) as liquid adhesives in combination solvents. With excellent strength and durability, good electrical properties, and ability to adhere to a variety of materials, the adhesives have found use in a number of electrical applications. They are also used as primers on metal for secondary gluing with resorcin or phenolic adhesives; for bonding plastic laminates to other materials; for bonding metal skins to resin-treated honeycomb core in sandwich construction; in the bonding of copper foil to plastic laminates for printed circuits; and for bonding of cork-and-rubber compositions to metal for clutch applications.

Most of the modified phenolic adhesives will bond to cyclized rubber, that is, rubber which has been surface-treated with sulfuric acid. In some cases they will also bond to untreated vulcanized rubber. Some unvulcanized rubber compounds may be bonded to metal or other materials during vulcanization through the use of these adhesives.

Nylon-Phenolic

Nylon-modified phenolic resins in solution form have shown excellent adhesion to a variety of surfaces, yielding bonds of high strength and good durability. Water resistance is not quite as good as the vinyl formal-phenolics, but the adhesives are generally quite acceptable for use in a variety of applications. Heat curing is required as with the other modified phenolic resin adhesives.

THIOKOL ADHESIVES

Products based on Thiokol polysulphide rubber should more properly be considered as sealers rather than adhesives, although in some applications the products are used as adhesives *per se*. Liquid Thiokol products are of most interest as adhesives. These are supplied as two-component products, one part consisting of compounded liquid rubber, the second part being a setting agent dispersed in solvent or plasticizer. Mixing of the two parts yields a mixture with a usable life from 15 minutes to several hours depending on formulation. This mixture subsequently sets to a rubbery solid. Small amounts of solvent are occasionally used for viscosity reduction. When solvent is not used in the formulation, shrinkage during setting is negligible; hence the wide use for this type of product in sealing applications.

Thiokols adhere to many metal surfaces, glass, wood, plastics, and cloth, with shear strengths in the range of 60 to 300 psi. Peel strengths are from 20 to 60 pounds per inch of width with flexible materials such as cloth, with strength depending on film thickness. Shear and tensile strengths are highest at minimum film thicknesses, whereas peel strengths increase as the film thickness increases. Liquid Thiokol adhesives have a definite advantage in bonding impervious materials such as plastics and glass because no volatile products need escape, and no drying is required. The adhesives cure at room temperature, attaining maximum strength in 4 to 7 days. Resistance to solvents, oil and grease, and exterior weathering and aging is superior to that of thermoplastic rubber type adhesives. Thiokols also excel in low temperature properties, remaining flexible at temperatures in the range of −75 to −85 F. Resistance to elevated temperatures is relatively poor, however, and the adhesives soften considerably at temperatures of 160 to 200 F, and above 250 F have practically no strength. Combinations of Thiokol with epoxy resins have resulted in adhesives which are somewhat better in this respect. Improvements in strength also have been realized. Thermoplastic tendencies are indicated by reduction in strength at elevated temperatures, and the adhesives are relatively poor under sustained stress, since cold flow occurs. Principal uses include sealing applications; bonding transparent plastic to glass in periscope production; potting; and bonding rubber to metal.

Table 5—Miscellaneous Water-Base Adhesives

Vegetable Adhesives

Starch and **dextrine** adhesives are supplied in dry powder form or as water solutions suitable for hand or machine application. Although they may be considered low in strength compared to some types of adhesives, they are usually used to bond paper, and strength is adequate for this purpose. They develop tack quickly, making them valuable for carton labeling and bottle labeling. Their light color and nonstaining characteristics are important in such applications. Susceptibility to mold growth and lack of water resistance are serious shortcomings for many uses, but these properties may be improved by compounding with urea resins and preservatives.

Soybean flour and Zein, vegetable proteins, find some application as plywood adhesives.

Animal-Base Adhesives

Glue, as a term, is restricted to designate hide, bone, and fish glue, and is not used as a generic term for "adhesive." Hide glues are supplied as dry flake or powder which, at time of use, are dissolved in water. They can be applied by hand or machine at elevated temperatures. Bonds are made before the glue cools and gels. Hide glue develops strengths greater than that of wood in bonded wood joints. It has good tack and sets quickly. Shelf stability of dry glue is good, but it is susceptible to mold growth and attack by vermin in the package before use, and also in the bonded joints. Water resistance is poor. Hide glue is primarily used in the furniture and other woodworking industries. Its excellent gap-filling properties are of value where close fits are not possible or economical. It has been used also for bonding leather, paper, textiles, and as a binder for abrasive wheels and abrasive paper. Bone glue is soluble in cold water. It finds extensive use in water-reactivated gummed paper tape, where its ready solubility in water, allowing fast reactivation, is important. It has been used also in the sealing of shipping containers. Fish glue is used primarily as a cold glue for woodworking. It does not require heat for solubility. All glues lack water resistance, although this property may be improved through the use of tanning agents. Resistance to mold and fungus may be improved through incorporation of proper preservatives.

Blood albumen is a light-colored powder which can be dissolved in water at time of use. It has good adhesion to paper, textiles, leather, cork and metals. It has been widely used in food packaging, as the bonds are odorless, nontoxic and tasteless. A typical food use is the bonding cork disks in metal bottle caps. In high speed operations it is set by heating to a temperature of approximately 180 F, which causes coagulation. It has fair water and heat resistance when set with heat.

Casein adhesives are supplied as dry powders, to be mixed with water. Casein has been used for many years as a wood adhesive. Fair water resistance can be obtained through proper compounding. Although casein is susceptible to mold and fungus attack, these properties may be improved through the use of preservatives. In bonding certain woods, alkalinity of casein adhesives has enabled better bonds to be obtained than may be realized with some of the resin adhesives.

Casein-latex adhesives have served for many years for bonding wood to metal for panel construction. They also are used for bonding laminated plastics and linoleum to wood and metal and other sub-bases. The adhesives consist primarily of combinations of casein with either natural or synthetic-rubber latex, in consistencies suitable for application by brush, trowel, or machine. They age well and have good strength. Although they are susceptible to moisture and mold growth, durability is adequate for interior use.

Inorganic Adhesives

Sodium silicate adhesives, in water solution, have the property of setting very rapidly by the loss of a relatively small amount of water. They have found extensive use in the manufacture of corrugated boxboard, where quick absorption of water into the paper allows fast machine speeds. Sodium silicate has excellent adhesion to paper. Water resistance is adequate for boxes and cartons, being better in this respect than the paper bonded. Water resistance may be improved by application of suitable salts to the paper surface prior to bonding. Being inorganic, sodium silicate is resistant to mold growth. It also finds some use in applications where heat resistance is important, as, for example, in mortars for firebrick.

Magnesium oxychloride cements find some use in the bonding of ceramics and glass where chemical resistance or heat resistance is important. Excellent bonds are obtained. The adhesive usually is supplied in two parts which are mixed at the time of use.

Litharge-glycerine adhesives have been used for potting applications with ceramics, and to make seals of various kinds for many years. The adhesive consists of a simple mixture of litharge and glycerine which sets chemically in about 24 hours. The compound is chemically resistant.

where large areas are involved, and the latter method is preferred. Escape of residual solvent also causes shrinkage of the adhesive film under such conditions, and faulty bonds may result. When the bonds are formed under heat and pressure, the pressure must generally be retained until the adhesive has cooled.

Thermosetting Rubber-Resin Adhesives: A few adhesives described in TABLE 1 as thermoplastic rubber adhesives, when heat-cured in the neighborhood of 300 F, may demonstrate shear strengths in metal-to-metal or metal-to-wood bonds in the neighborhood of 1500 psi. This property is particularly true of Buna-N and neoprene thermo-

Table 6—Factors Influencing Adhesive Selection

STRESS

Tension ..... Forces acting perpendicular to the plane of the adhesive. Not commonly encountered in bonding thin plastic or metal sheets, leather, cork compositions, etc.

Shear ..... Forces acting in the plane of the adhesive. Pure shear is seldom encountered in adhesive assemblies; substantial tension components are usually found.

Impact ..... Minimum force required to cause the adhesive to fail in a single blow. May be determined in tension or shear. Measures brittleness.

Peel ..... Stripping of a flexible member fastened with adhesive to another flexible or rigid member. Stress is applied at a line; test loads are expressed in pounds per inch width. Commonly used angles of peel in tests are 90 degrees for relatively stiff and 180 degrees for flexible members.

Cleavage ..... Forces applied at one end of a rigid bonded assembly which tend to split the bonded members apart. Can be considered as "peel" of two rigid members.

Fatigue ..... Dynamic—alternate loading in shear or tension-compression. Static—maximum load sustained for long periods of time in tension or shear; tests are also used to determine creep.

CHEMICAL FACTORS

External ..... Effect of chemical agents such as water, salt water, gasoline, by hydraulic fluid, acids, alkalies, etc.

Internal ..... Effect of adherend on adhesive (i.e., exuded plasticizers in certain plastics and rubber); effect of adhesive on the adherend (crazing, staining, etc.).

EXPOSURE

Weathering ..... Combined effect of rainfall, sunlight, temperature changes, type of atmosphere.

Light ..... Important only with translucent adherends. Effect of artificial or natural light, or ultraviolet.

Oxidation ..... Usually tested by exposure to ozone either with the joint unstressed or stressed, in which case deterioration is faster.

Moisture ..... Either adhesive or adherend may be affected by high humidity or wet conditions. Cyclic testing with alternate moist and dry conditions can be valuable. May cause dimensional changes.

Salt Spray ..... Important only in coastal or marine atmospheres. Possible corrosion of adherend should also be considered.

TEMPERATURE

High ..... Normal atmospheric variations may be encountered, or exceptional conditions. Bond strength may be affected by reactions in adhesive or adherend; decomposition or changes in physical properties of adhesive are important.

Low ..... May cause crystallization or embrittlement, detected by strength test. Cyclic testing with low or high temperatures may detect lack of durability.

BIOLOGICAL FACTORS

Bacteria or Mold ... Usually warm, humid tropical conditions. Can affect bond strength, and cause emission of odor or discoloration.

Rodents or Vermin .. Adhesives of animal or vegetable origin may be attacked by rats, cockroaches, etc.

WORKING PROPERTIES

Application ..... Brushing, spray, trowel or knife-spreader application characteristics are usually determined by trial and error. Consistency or viscosity may be adequate indications. Mechanical stability of emulsions and dispersions, and foaming tendency, can be important for machine application.

Bonding Range ..... Minimum drying or solvent-reactivation time before suitable bond can be obtained. Maximum allowable time before assembly. Permissible temperature range with heat-activated adhesives.

Blocking ..... Tendency of surfaces coated for storage before assembly to adhere under slight pressure, or changes in humidity or temperature.

Curing Rate ..... Minimum curing time, and effect of overcuring. May be determined as a shear or tensile-strength versus curing-time curve at a specific curing temperature.

Storage Stability .... Physical and chemical changes in original unapplied state as a result of storage for extended time periods at representative storage temperatures.

Coverage ..... Area of bond that can be formed with unit weight or volume of adhesive; expressed as pounds per 1000 feet of bond line, or square feet per gallon. Depends on method of application; dimensions of work or of adhesive-coated area in relation to part size may affect coverage.

plastic adhesives, but is possible only with those compounded with thermosetting resins and curing agents for the rubber. By curing such adhesives, resistance to chemicals of various kinds is improved. Strength is also improved, and the adhesives are up-graded generally. By reducing thermoplasticity of the bond, cold flow is reduced, the adhesives are able to sustain higher dead loads, and are useful over a wider temperature range. They are not nearly as strong, however, as adhesives especially formulated for heat curing. Such specially formulated rubber-resin adhesives are outlined in TABLE 4.

Thermosetting Resin Blends: The rubber component in the adhesives just discussed serves as a plasticizer for the resin, toughening the resin and raising impact strength. Rubber also introduces some elasticity which improves stress-distributing properties. However, thermosetting resins may be plasticized not only with rubber, but also with thermoplastic resins. A number of adhesives have been developed from phenolic resins modified with nylon or vinyl resins of several types, TABLE 4. Such adhesives might more properly be called "thermosetting-thermoplastic" adhesives. Properties are much closer to those of the thermosetting adhesives than the thermoplastics; some of the products are suitable for bonding metal to metal for structural purposes.

Miscellaneous Water-Base Adhesives: Adhesives manufactured from raw materials of animal or vegetable origin, TABLE 5, were the first adhesives used by mankind, and continue in use today in large volume. Although little used in many industrial applications because of limited durability, they are important in bonding wood and paper.

CHOOSING AN ADHESIVE

In view of the variety of adhesives commercially available, it might be expected that the problem of choosing the best adhesive for a given application would be difficult. However, by the process of elimination with due consideration to the various factors involved, the broad field of adhesives can be narrowed to one or perhaps two types of adhesives most likely to be successful. Then the ultimate choice can be made among the available commercial products of the appropriate type. Most satisfactory results are often obtained with an adhesive designed to do a specific job, and many times the properties of available products will not exactly meet the requirements. Almost every adhesive application requires compromise between what the potential user wants and what is obtainable. The main problem often is deciding which factors are of major and minor importance, and how the compromise can be made most advantageously; some of these factors are outlined in TABLE 6. It is impossible to cover completely all the details entering into the choice of an adhesive. Only the general thought processes involved can be illustrated.

Materials To Be Bonded: Certainly first consideration must be given to the determination of types of adhesives which will adhere to the materials to be bonded; typical adhesive-adherend combinations are given in TABLE 7. Adhesion may occur in a number of ways. Some of these are: softening action and fusion of the adhesive with the adherend; chemical reaction of the adhesive with the adherend; so called "specific" adhesion; through mechanical interlocking of the adhesive in the interstices of the adherend; or through sheer fluidity or tackiness. Whatever the cause of adhesion, it is well known that certain types of adhesives will not adhere to some surfaces. These may be eliminated from consideration in choosing an adhesive where those surfaces are involved.

A commonly accepted fact is that good adhesion exists when the adhesive fails in cohesion after testing the joint to destruction. With failure in cohesion, adhesive uniformly covers both of the bonded surfaces. Although adhesion of this order has been considered desirable, cohesive failure is not necessarily a valid requirement. Adhesives might be compounded to reduce the level of cohesive strength below the level of adhesion strength, and thus exhibit cohesive failure. Higher strength values might be obtainable with adhesives which fail in adhesion. Certainly the visual adhesion, as such, is of less importance than the strength of the assembly. Strength should be accepted as a factor of greater importance.

Often the adherends are the limiting factors in the ultimate strength of the bond. With relatively weak adherends an adhesive should be used which is stronger than the materials to be joined under all conditions of use; then the adhesive is surely not the weakest link in the chain. For example, most of the adhesives used for bonding felt to metal are stronger than the felt. Most of the durable adhesives used for wood adhere with a tenacity greater than the strength of the wood itself. Thickness and the strength of the adherends also influence choice of an adhesive where design of the joint is such that the elastic constants of the adhesive assume major importance.

Chemical nature of the adhesive and its constituents, and their affect on the adherend, should also be considered. Some materials are softened by solvents which are necessarily used in certain adhesives; effect of such solvents may be objectionable. Also, chemical reaction between the adhesive and the adherend may produce undesirable byproducts which would eliminate the adhesive from con-

sideration. Materials which are softened with heat cannot be bonded readily with adhesives which require heat and pressure for establishing the bond. Other factors of this type involving the adherends may occur when a specific problem is being considered. Each serves to eliminate from further consideration some types of adhesives.

Service Requirements: All of the exterior conditions which may affect the adhesive joint should be considered, and these too will probably narrow the choice still further. Stress and resistance to deterioration are two of the prime factors involved. Characteristics of adhesives have already been discussed; however, TABLE 8 provides a summary for thermoplastic rubber adhesives, TABLE 9 for wood adhesives, and TABLE 10 for structural adhesives.

A suitable adhesive must have adequate strength to hold the bonded parts together through the expected life of the assembly. Its strength must be maintained to a useable degree under the service conditions encountered. As previously mentioned, adhesives with bond strength greater than the strength of the materials bonded can sometimes be used, but such use is by no means always necessary. Actually, it may be economically impractical. The ideal adhesive is one with adequate strength to do the job, allowing reasonable safety factors. From a practical standpoint all bonded assemblies do not require the strongest adhesives that may be obtained. Strength of the adhesive should be matched to the strength requirements of the application. A realistic approach to choosing an adhesive on this basis will result in the right adhesive being used in the application. Proper consideration of the strength requirements can serve to narrow further the field of available adhesives to be considered. Those known to be stronger or weaker than the requirements can be eliminated.

Adhesives vary widely in strength properties from soft, sticky products to rigid products with strengths of several thousand psi. Strength requirements must be judged on the basis of the type of stress applied in service, that is, whether the stress is in shear, tension, or peel. Also significant is the rate at which the stress is applied—whether as an impact, a continuous constant stress, or a vibratory stress. Adhesives behave differently under different stresses and stress rates. For exam-

Table 7—Typical Adhesive-Adherend Combinations

Adherends	Wood	Vinyl Sheeting (unbacked)	Rubber	Phenolic Plastic	Paper or Cardboard	Leather	Fabric	Ceramics (glass)	Aluminum or Steel
Aluminum or Steel	1 3 6 7 8 10	1 2	1 2 6 7	1 2 5 6 7 8	1 2 3 4 5	1 2 3 4 8	1 2 3 4 8	6 7 8 10	6 7 8
Ceramics (glass)	1 3 6 7 8 10	1 2	1 2 6 7	1 6 7 8	1 2 3 4 5	1 2 3 4 8	1 2 3 4 8	6 7 8 10	
Fabric	1 2 3 4 5	1 2	1 2	1 2 3 4 5 8 9 10	1 2 3 4 5	1 2 3 4 8	1 2 3 4		
Leather	1 2 3 4 5	1 2	1 2	1 2 3 4 5 8 9	1 2 3 4 5	1 2 3 4 5			
Paper or Cardboard	1 2 3 4 5	1 2	1 2	1 2 3 4 5	3 5				
Phenolic Plastic	1 2 8 9	1 2	1 2 6 7	6 7 8 9					
Rubber	1 2 6 7	1 2	1 2 6 7						
Vinyl Sheeting (unbacked)	1 2	1 2							
Wood	3 9								

Adhesives

1. Solvent rubber
2. Rubber latex and dispersion
3. Resin emulsion
4. Solvent resin
5. Vegetable or animal
6. Rubber-phenolic (thermoset)
7. Phenolic-vinyl
8. Epoxy
9. Urea, melamine, resorcin, or phenolic
10. Thiokol

Table 8—Thermoplastic Rubber Adhesives*

Adhesive Rubber Base	Strength	Deadload	Tack	Resistance to: Water	Oil	Gasoline	Heat	Cold	Aging
Buna N	E	F	P-G	E	E	E	G	G	G
Butyl	F	P	G	E	P	P	P	G	E
GR-S	F	P	F	E	P	P	F	G	F
Natural	G	P	E	E	P	P	P	G	F
Neoprene	E	G	P-G	E	G	G	G	G	G-E
Reclaim	G	P	G	E	P	P	P	G	F
Thiokol	F	P	F	E	E	E	F	E	E
Rubber Derivatives									
Cyclized	G	F	G	E	P	P	F	M	G
Chlorinated	G	F	G	E	G	G	M	M	G

*Code: E—excellent, G—good, M—moderate, F—fair, P—poor.

ple, thermosetting resin or rubber-resin adhesives can show high tensile or shear strength, excellent resistance in most cases to constant stresses of a rather high level applied over a long period of time. They exhibit good fatigue properties or resistance to vibratory stress. The same adhesives, however, may be relatively poor under peel or cleavage stresses. On the other hand, many thermoplastic resin adhesives exhibit poor resistance to continuous or vibrating stresses of high magnitude, even though exhibiting in some cases high shear or tensile strength in tests of short duration. Thermoplastic rubber-based adhesives show high peel strengths but have relatively low tensile or shear strengths.

Where impact loading is to be encountered, a tough, resilient adhesive would be better than a brittle one. If high strength is required with good fatigue resistance, thermosetting adhesives are indicated. Adhesives are also available with intermediate properties that fall in a shadowland between the thermosetting and thermoplastic products. These will sustain dead loads or constant stresses of the order of 100 psi indefinitely.

In choosing an adhesive for a given peel strength or impact strength requirement, it should be borne in mind that film thickness of the adhesive has an influence on performance. Higher strengths are usually obtained in impact with greater film thicknesses of nonbrittle adhesives. Higher peel strengths generally are obtained with elastic adhesives at greater film thicknesses. Tensile strength and shear strength are greater with high-modulus adhesives at minimum film thickness, although at very low film thicknesses of the order of 1 mil and below, tensile and shear strengths decrease below the optimum. Due consideration of the type of stress and rate of stress application is necessary to choose the proper adhesive.

Adhesives in service are subjected to a number of deteriorating influences, depending of course on the end-use. Many may affect the strength of the adhesive, and the adhesive should retain a useful strength level after exposure to such influences. Among the things that might change the strength properties are water, oil, solvents, brake fluid, high and low-temperature exposure, exterior weathering, and normal aging. In choosing an adhesive a realistic approach must be taken to the permanence question, again relating the properties of the adhesive to the end-use. If water resistance at normal room temperatures is desired, requiring adhesives to withstand boiling water may result in the elimination of otherwise satisfactory products. If oil resistance is required and glycol resistance is not, the adhesive should be chosen for performance in oil, and effect of glycol disregarded.

Adhesives vary widely in their resistance to

Table 9—Wood Adhesives*

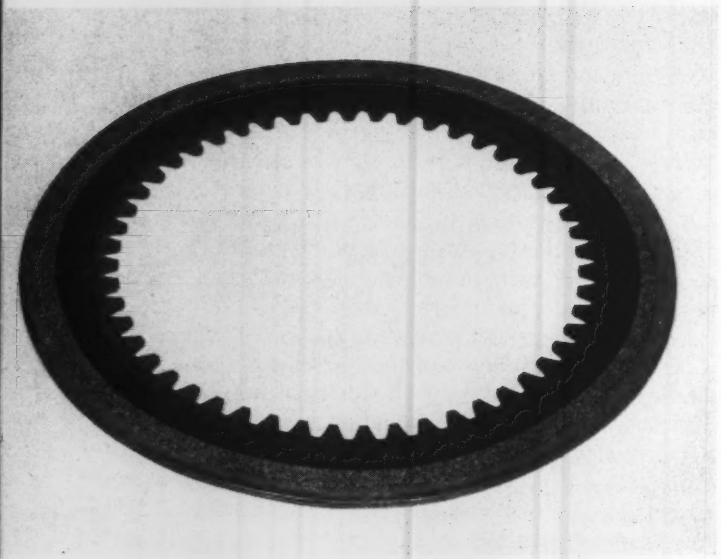
Adhesive	Supplied as	Mix with	Pot Life (hr)	Sets at (deg F)	Resistance to: Water	Weather	Fungus	Heat	Solvents	Suitable for
Animal glue	Powder	Water	Indef.	70	P	P	P	P	E	Interior
	Flake	Water								
Casein	Powder	Water	1-24	70	F-M	P	F	G	G	Interior
Melamine	Powder	Water	24-48	240-280	E	G	E	E	E	Exterior
Phenolic, acid catalyst	Liquid	Hardener	1-6	70-210	E	E	E	E	E	Exterior
Phenolic, hot set	Liquid	....	Indef.	250-300	E	E	E	E	E	Exterior
	Film	....	.....							
	Powder	Water	Indef.							
Resorcin or phenolic	Liquid	Hardener	1-6	70-210	E	E	E	E	E	Exterior
Urea	Powder	Water	1-24	70-210	G	M	E	M	E	Interior
	Liquid	Hardener								
Vinyl acetate	Liquid	....	Indef.	70	F-M	P	G	P	F	Interior

*Code: E—excellent, G—good, M—moderate, F—fair, P—poor.

Table 10—Structural Adhesives*

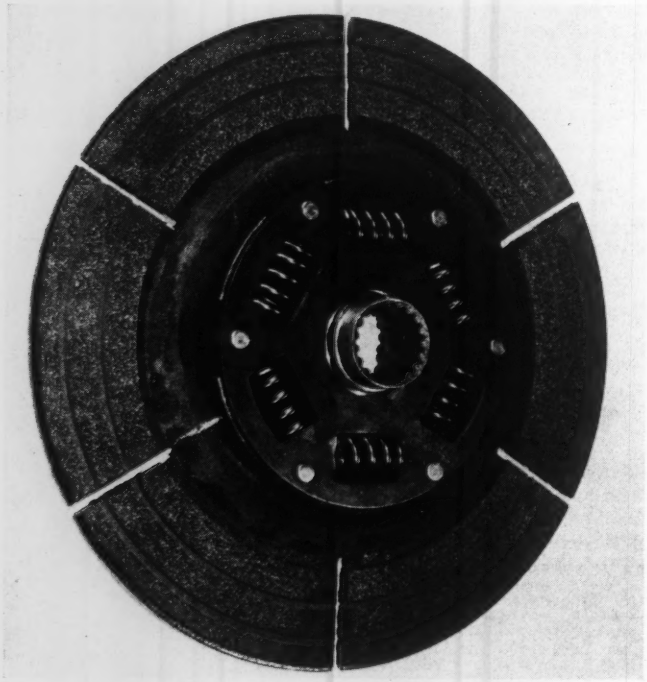
Adhesive	Supplied as	Mix with	Requires Drying	Cures at (deg F)	Resistance to: Water	Oil	Gasoline	Glycol	Heat	Cold
Epoxy	Liquid	Hardener	No	70-250	F-G	E	E	G	F	G
	Powder	....	No	250-500	F-G	E	E	G	G	G
	Rod	....	No	250-500	F-G	E	E	G	G	G
Polyester	Liquid	Hardener	No	70-220	G	E	E	E	G	M
Phenolic-vinyl	Liquid	....	Yes	240-500	E	E	E	E	G	G
	Film	....	No	240-500						
Phenolic-Buna-N	Liquid	....	Yes	325-500	E	E	E	E	E	P-G
	Film	....	No	325-500						
Phenolic-neoprene	Liquid	....	Yes	325-500	E	E	E	E	G	E
	Film	....	No	325-500						
Phenolic-polyamide	Liquid	....	Yes	325-500	G	E	E	G	F-M	G

*Code: E—excellent, G—good, M—moderate, F—fair, P—poor.



Photo, courtesy Detroit Transmission Div., General Motors Corp.

CLUTCH DRIVE PLATE used in the Hydra-Matic transmission is one of a set used to provide the driving force to obtain direct drive. It is fabricated by bonding cork and impregnated-paper facings to both sides of a splined steel center-plate. Facings are then assembled, clamped in position and baked at 300 to 310 F for 15 to 20 minutes to complete the bonding.

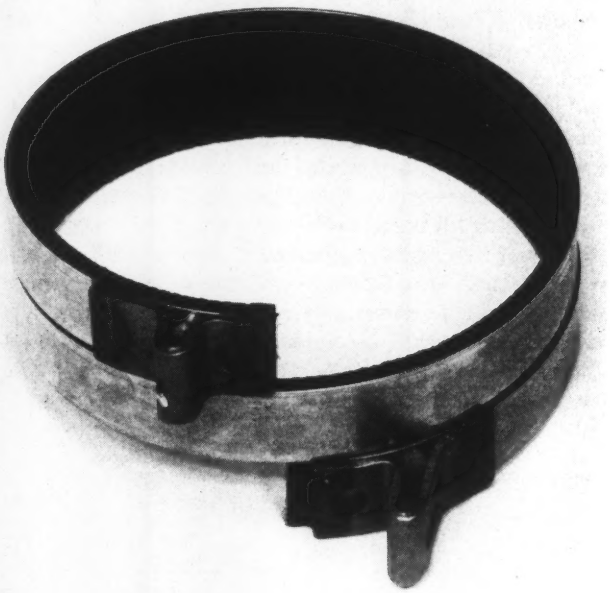


Photo, courtesy Long Mfg. Div., Borg-Warner Corp.

CORK LININGS are bonded to both sides of a steel center-plate in this lock-up clutch. Providing a friction lining for the torque-converter clutch, the cork is assembled in separate circular segments and bonded to the disk.

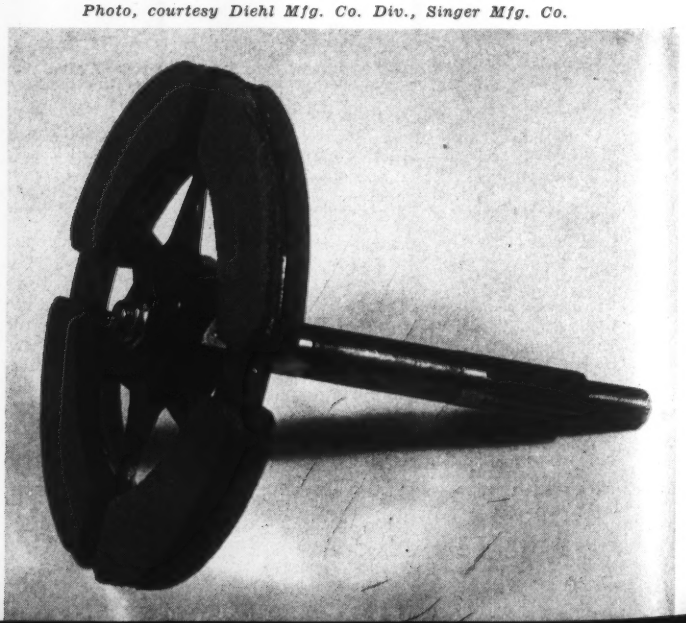
FRONT BAND ASSEMBLY for a Hydra-Matic transmission consists of a strip of woven lining bonded to a coiled steel band. Applied in first and third gears, the assembly provides the holding force to obtain reduction through the front unit gears of the transmission. A film adhesive is applied to the back of the lining, which is then assembled into the band. The band is then clamped in position around a drum and immersed in a hot oil bath for bonding.

Photo, courtesy Detroit Transmission Div., General Motors Corp.



BRAKE AND CLUTCH for industrial sewing machine drive carries cork composition friction surfaces bonded to both sides of the clutch-brake disk. One side acts as the brake; the other as the clutch. Adhesive is a thermosetting synthetic resin type.

Photo, courtesy Diehl Mfg. Co. Div., Singer Mfg. Co.



chemical deteriorating agents, temperature extremes, and weatherability, as previously pointed out. Generally speaking, thermoplastic adhesives are not resistant to chemicals similar in solvent properties to the solvents used in making the adhesive. They are not resistant to high temperatures. As a class, the thermosetting products exhibit good chemical resistance. They are useable over a wider temperature range, both high and low, and generally are satisfactory from a permanence standpoint.

An adhesive application involving service at 160 F could be solved by the use of thermosetting adhesives of several basic types. Adequate bonds may be found also in the thermoplastic rubber adhesives or some resin adhesives, depending on strength requirements. On the other hand, at service temperatures of 250 F, thermosetting products alone will be adequate, although intermittent exposure at low stress levels might permit the use of certain thermoplastic rubber adhesives. At service temperatures above 250 F, the more heat-resistant thermosetting adhesives, such as Buna-N phenolic products, will be required. Again the type of stress and rate of stress application assumes importance. At elevated temperatures all adhesives lose some of their strength. Thermoplastic adhesives particularly are considerably weaker than at room temperature under constant conditions.

Special factors encountered in specific applications also may serve to indicate the suitability of certain types of adhesive and the inadequacy of others. For instance, the solvent in some adhesives or the plasticizer used in formulation may craze acrylic plastics under stress. In most cases this is objectionable, and such adhesives cannot be used. A number of adhesives are softened by the exudation of plasticizer from flexible vinyl sheets or from rubber, particularly rubber compounded for low temperature resistance, while other adhesives are not softened.

To obtain an adhesive with adequate properties, without at the same time making excessive unimportant demands, the permanence required of an adhesive must be related judiciously to service.

Assembly Requirements: Conditions under which an adhesive bond is to be made serve also as criteria for discrimination between types of adhesives and between adhesives of a given type. Circumstances often exist which affect the bonding operation and make certain properties in the adhesive necessary. For instance, field repair operations require adhesives which will bond under field conditions. In production-line operations the bonding must sometimes be accomplished in a matter of minutes. Typical factors involved in assembly are: the type of application equipment necessary, desirable or available; temperature at which the bond must be made; time allowable from coating to bonding; required rate of strength development; heat and/or pressure limitations during assembly; etc.

Method by which an adhesive may be applied to the work is influenced by size and shape of the parts, relationship between the area to be coated and the geometry of the part, and the number of parts to be coated. Adhesives are available in a range of consistency from thin liquids to heavy pastes, generally available in all the various types of adhesives. Consistency and application properties of the adhesive are important because all consistencies do not apply equally well by the different methods. The adhesive must be matched to the application means or vice versa.

Tack of an adhesive is an important assembly property. It is the property which allows a bond to be formed as soon as the parts are brought together. Also, the tack range—the minimum and maximum time over which a bond may be made after the coating operation—must be considered. Tack properties of adhesives vary widely from type to type and within given types. Most of the thermosetting adhesives have very little tack. Others, such as the rubber adhesives, some resin adhesives, oleoresinous products, and some latex products, have good tack. Solvent rubber cements and latex rubber adhesives both may exhibit good tack in the dry or partially dry state. However, solvent rubber adhesives are tacky even while containing considerable solvent, whereas the latex adhesives must lose most of their water before high tack develops. Some resin emulsions and latex products are used in applications where tack requirements are relatively low. In such cases they demonstrate adequate wet strength immediately after application to the work. In some applications temperature at which the bond must be made, or the temperature to which the bonded assembly will be exposed immediately after the bond is made, influences the selection of the adhesive. Although most bonding is done at room temperature or at elevated temperatures, some adhesives are expected to bond at low temperatures. This requirement alone eliminates from consideration those adhesives which freeze in the container or which increase in consistency at low temperatures to the point where they cannot be handled. Many thermosetting adhesives require heat and pressure to make the bond. This assembly requirement may or may not be attainable in specific applications, and a room-temperature thermosetting adhesive may be best suited. Temperature to which a bonded article may be subjected immediately after the bond is formed assumes importance where paint baking operations may be involved. For example, weather stripping may be adhered to automobile bodies before baking operations, and the bond is expected to be maintained at the elevated temperatures.

Cost of Adhesives: Cost of an adhesive is a consideration, but it assumes importance only after products with suitable properties and quality have been determined. Many cases could be cited where low-priced adhesives do a better job with all factors considered than higher priced products. But

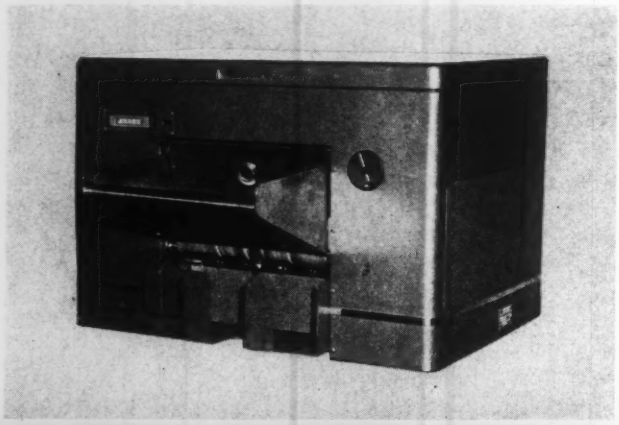
cost of an adhesive cannot be evaluated solely on the basis of price per gallon or price per pound.

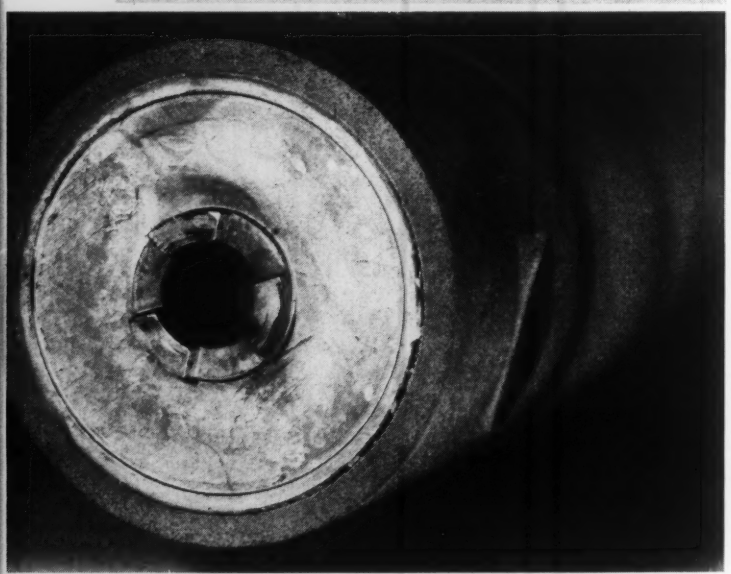
Coverage, for instance, must be taken into consideration. The number of parts that can be assembled with a gallon or pound of adhesive determines the cost per part. Method of application enters into the cost. Some application devices waste more adhesive than others. A change in adhesive and method of application may reduce overall cost, even though the adhesive is higher priced. Additionally, suitability of the adhesive to the job also influences the cost decision. A borderline adhesive which results in an excessive number of rejected parts is expensive regardless of its price.

Consideration should always be given to economies that might result in the bonding operation through the use of an adhesive which, although higher priced, might possess working properties allowing such economies to be made. For example, parts which must be held under pressure while the adhesive is setting may be more economically assembled with a higher priced adhesive not requiring retention of pressure. But above all, first consideration should be given to the selection of adhesives with the proper characteristics which will insure satisfactory performance of the bonded assembly.

FEED DRUMS in this Recordak Bantam microfilmer consist of rubber-cork tubing bonded with a solvent type synthetic rubber adhesive to the metal drum.

Photos, courtesy Eastman Kodak Co.





BONDING TECHNIQUES

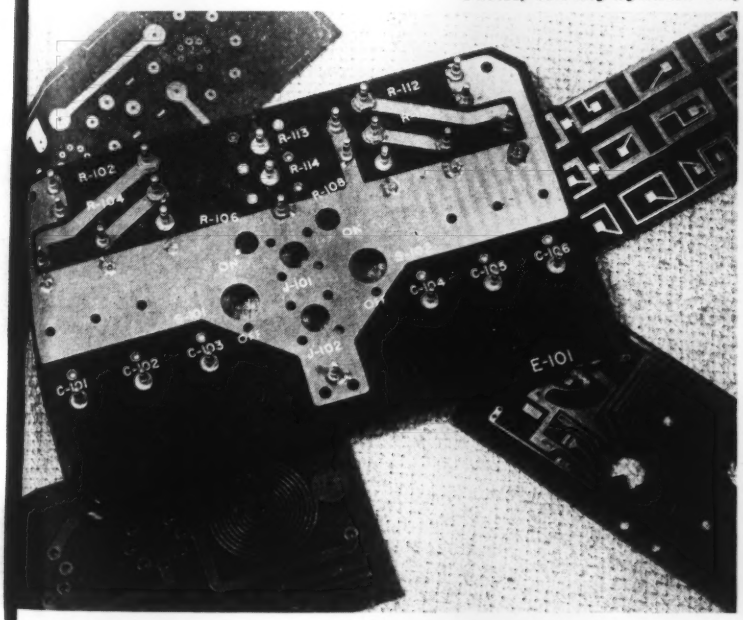
The joining of surfaces with an adhesive consists of a series of individual operations, each of which must be done properly to achieve the desired end result. Number of operations and the method of making the bond depends on several factors, such as the type of materials to be bonded, the adhesive to be used, the physical size and design of the parts involved, and the facilities available. Details of the various methods of surface preparation, application, assembly and curing are given in TABLE 11. However, certain methods and techniques are common to all types of joining operations, and deserve more extensive discussion.

Surface Preparation: All adhesives require clean surfaces to attain optimum results. The amount of surface preparation necessary or desirable may be influenced by the type of adhesive used and the ultimate requirements of the bond. Condition of a surface at time of bonding depends on conditions of storage of the parts, and type of processing prior to bonding. Nonstructural adhesives, such as the pressure-sensitive types, rubber cements and asphalt adhesives, perform satisfactorily if the surface is free of dust and dirt, grease and oil, loose scale, corrosion products and other loosely bonded coatings. Cleanliness of surface for adhesives of this type is not as critical as for structural adhesives. Amount of work to be done in preparing the surface should be decided with consideration given to the final bond desired and practical economic conditions existing.

Where high-strength bonds are required, surface preparation necessarily must be thorough. Recommendations of the manufacturer of the adhesive should be followed. Metal surfaces should be free of surface contaminations, which may be accomplished mechanically or chemically, or through combination of both mechanical and chemical means. Chemical cleaning is preferred where the size of the production operation warrants installation of the proper equipment. Mechanical methods have been found desirable on those operations where the number of assemblies to be bonded is small, or where the construction or condition of parts when they arrive at the bonding operation is

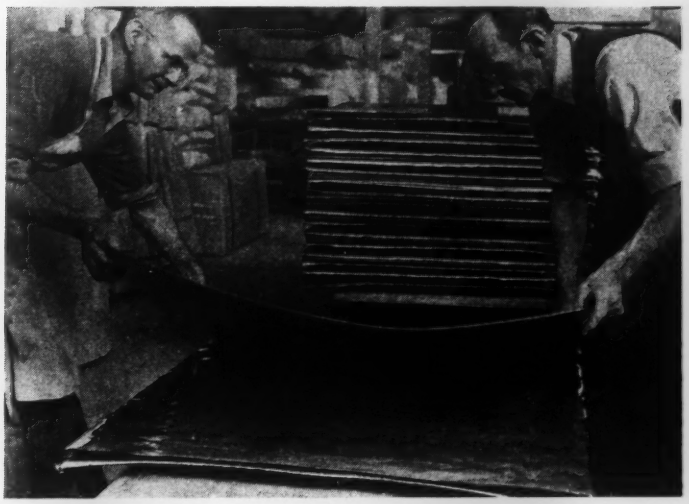
PRINTED CIRCUITS, in one type of production, are made by etching foil-clad plastic laminates. The basic material consists of thin copper foil bonded—usually with a thermoplastic-thermosetting resin blend adhesive—to one or both sides of paper-base high-pressure laminates.

Photos, courtesy Synthane Corp.



Circuit materials to meet close thickness tolerances are produced by assembling a sanded, curved sheet of laminate, a dry film adhesive and the foil in proper order. Where thickness tolerance is less critical, a number of uncured, resin-impregnated sheets may be used in place of the cured laminate.

Each sheet of foil-clad laminate is then sandwiched between clean, smooth steel press plates. These assemblies are stacked for insertion in a hydraulic press.



Stacks of press plates and laminates are loaded in a hydraulic press; ends must be carefully aligned. After one hour at 350 F and 1000 psi, the adhesive material has polymerized to form a strong bond between the foil and laminate.

Table 11—Bonding and Assembly Methods

SURFACE PREPARATION

Aluminum

May be cleaned with acidic or alkaline cleaners. Preferred alkaline cleaner of sodium metasilicate and a wetting agent in water at a temperature of 160 to 180 F cleans aluminum in 4 to 5 minutes. Aluminum should be immediately rinsed with water. A chromic acid rinse after alkaline cleaning prevents corrosion by residual alkali. Cleaning methods for spot welding are satisfactory for bonding. Phosphoric acid cleaners should be checked with the specific adhesive, as should propietary cleaners of all types. Preferable acidic cleaner consists of a solution of sulphuric acid and sodium dichromate at 140 to 160 F; bonds made after this type of cleaning may have better resistance to salt spray.

Steel

Should be free of rust and mill scale as well as dirt and grease, accomplished by an alkaline cleaner to remove grease and dirt followed by an acid pickling operation. Pickling of high-carbon steel and certain alloys often leaves a smut or residue which may be removed mechanically while wet or chemically with oxidizing agents. Suppliers of cleaning compounds should be consulted when such conditions are present. Clean steel parts should be coated as soon after drying as possible to minimize rust formation.

Magnesium

May be cleaned by brushing lightly with a fine wire brush followed by hot alkaline cleaner and water rinse, or by anodizing processes. Magnesium supplied with conventional surface treatments sometimes can be used as is, but surface contamination should be removed with solvent. Common practice in the aircraft industry is to clean the metal, apply a coat of zinc-chromate primer and bond right over it; improved corrosion resistance and minimum surface contamination can be expected.

Plastics

Phenolic and similar thermosetting plastics should be sanded to remove mold finish and mold release agents prior to bonding. Flexible vinyl plastic sheets normally require no cleaning other than surface dirt removal. Occasionally exuded plasticizer may be found, which must be removed; extreme care in adhesive selection should also be exercised. Other plastics may be wiped with a solvent; however, true solvents for the plastic normally should not be used as they may cause excessive softening, crazing and cracking. Light abrasion of transparent plastics also helps.

Vulcanized Rubber

Vulcanized rubber parts are often contaminated with mold release agents, or by plasticizer or wax exudation. Silicone mold release agents cause poor bonds, as the silicone greatly impairs adhesion to the rubber. Talc and water-soluble mold release agents may be removed by washing with water; plasticizer and wax by washing with solvent. Solvent depends on the specific rubber; toluol generally is satisfactory. Light abrasion of the rubber surface sometimes improves adhesion. Sometimes cyclizing with concentrated sulphuric acid is required for adequate bonds.

Wood

Should be surfaced at the time of bonding, preferably by planing rather than sanding when making high-strength wood joints. Surface should be free of dust. For wood-to-metal bonds the same high-strength preparation should be used. If only low-strength bonds with non-structural adhesives are involved, only normal removal of dust, dirt and grease is necessary.

Paper, Felt, Cloth

Surface preparation ordinarily is not required with paper, felt, chipboard or cloth. Dust and other obvious surface contaminations must be removed, or the material rejected as unfit for bonding.

APPLICATION OF ADHESIVE

Manual Brushing

Widely used for a limited number of assemblies, for assemblies of complex shape, or where only part of the surface is to be coated and masking would be impractical. Uniform film thickness is difficult to obtain; production rate is slow. Chief advantages are simplicity, and minimum cleanup and waste.

Flowing

Flow brushes, hollow brushes through which adhesive is fed by air pressure, provide continuous or intermittent flow. Rate of production is higher than conventional brushing, cheaper, and more uniform. Flow guns are used to deliver adhesive to the work in stripes of a maximum width of about 1 inch. Heavy adhesives and sealers can be applied; adhesives too heavy to flow properly may be delivered by a positive displacement pump. "Glue guns," automatically operated flow guns, are used to apply flat ribbons of adhesive, and to coat recessed surfaces. Thinner adhesives are required. Many machines have also been designed for spotting adhesives; these deliver adhesive by air pressure and synchronize adhesive delivery with work position.

Spraying

Spray apparatus and technique are similar to those for paint application. Some adhesives cannot be sprayed satisfactorily. Large areas, compound curves, and complex shapes can be covered economically. Drying time of the adhesive is usually shortened. Some adhesives require several spray coats to obtain optimum film thickness or uniform coating. Sufficient drying time must be allowed between coats to minimize sagging, bubbling or blistering; if the drying time is too long, succeeding coats may lift previous coats through solvent penetration. Automatic spray equipment is economical for long runs of identical parts; advantages are low labor cost and uniformity of film, but rigid control of viscosity is required.

Dipping

Not used widely, but of value in specific cases. The most satisfactory operations are automatic, since film thickness depends on rate of withdrawal from the bath and hand operations often are not uniform. Dipping coats the entire part area in contact with the bath, in some cases undesirable. However, adhesives which are tack-free when dry can sometimes serve as protective coatings over unbonded areas, and total immersion is also of value where multiple laminations are involved with relatively thin films of adhesive. Modifications are used to apply adhesive to flat surfaces of small parts by controlling depth of immersion. One type is basically a stamp-pad operation; a second type consists of a spring-loaded screen which descends into the bath to a predetermined depth. These methods are adaptable to hand operations on small numbers of small parts.

Silk Screening

Successful where adaptable. If adhesive must be applied to certain portions of a flat sheet, a mask may be made by the silk screen process, filling the pores in a cloth over areas where no application is desired. When such a filled cloth is placed over the work and adhesive poured on top of it, the unfilled portions of the cloth allow passage of adhesive to the work. The process is limited to low-viscosity adhesives and relatively thin films.

Roll Coating

For application to flat sheets. A roll coater consists of one or more rolls; one roll picks up adhesive which is then doctored by secondary rolls or knives to the proper film thickness for transfer to the work. Roll coating is particularly adaptable to long runs of continuous sheets, and is recommended for relatively large runs at high production rates of large or small parts. Roll coaters vary from less than 6 inches in width to 72 inches for single or double surface application. Roll-coat application is generally preferable for large flat surfaces rather than for small die-cut parts of unusual shape; it may be more economical to coat large sheets and waste the adhesive between various parts cut from it than to coat small individual parts.

ASSEMBLY TECHNIQUES

Wet Assembly

Involves positioning of faying surfaces while the adhesive is liquid and retaining the relative position until the adhesive sets or develops its bond strength. With porous materials such as wood or paper, adhesives can set chemically, or through the loss of volatile material, or merely through cooling as with hot melts. With nonporous materials, such as metal and plastics, loss of volatile material is practically impossible except at edges; with these materials, adhesives which set through chemical action, through cooling, or through polymerization or condensation at elevated temperatures can be used. To retain the bonding surfaces in proper position, pressure is required until the adhesive sets or partially sets, although in some cases the adhesive may be tacky enough to maintain position without pressure. The advantages of wet assembly are: relatively low pressure requirements; ease of obtaining accurate alignment if mistakes in positioning are noticed before the adhesive sets; and little or no floor space requirement for drying of adhesive-coated parts in process. Conversely, pressing jigs may be necessary, and on large operations the amount of floor space involved can be substantial.

Pressure-Sensitive Bonding

Involves only the application of pressure to adhesive-coated surfaces to accomplish the bonding. With soft, tacky adhesives, commonly designated "pressure-sensitive" types, application of adhesive to only one surface may be required. Rubber adhesives and resin adhesives with inherently higher strength than the softer, truly pressure-sensitive products generally work best with both surfaces coated. With an adhesive applied to both surfaces, good bonds generally can be obtained. If adhesive is applied to only one surface more solvent must remain in the film at time of bonding to permit transfer of the adhesive. With Buna-N, neoprene, and reclaim-rubber adhesives there is generally enough residual tack in the films after solvent evaporation, but tack range varies with each adhesive. In combining nonporous surfaces, the maximum amount of solvent should escape before assembly. Where one of the surfaces is permeable, the adhesive films need not be as dry. Generally, pressure - sensitive adhesives develop a reasonable share of their strength as soon as assembly is completed. Pressure requirements are generally low; often a hand roller will be found sufficient. Pressure need be retained only long enough to obtain surface contact, usually instantaneous. In bonding impervious materials with adhesives that lack adequate tack range for easy assembly, an inserted inner liner of cotton duck or chipboard helps the volatile material to escape; the adhesive can be used in a softer condition than permissible where no volatile escape is possible.

Solvent Reactivation

Involves the reactivation or retackifying, immediately prior to assembly, of an adhesive surface that has completely dried. Particularly useful where adhesives have an excessively long drying time, and parts can be stored until required. Many adhesives can be reactivated by volatile solvent, which softens the surface layers and allows fusion under pressure during assembly. Adhesives which tend to skin-dry and lose tack at the surface can be handled in this manner to develop higher immediate bond strengths. For convenience in assembly, activation with a solvent combination rather than a single solvent is sometimes desirable. The combination may be composed of a relatively fast evaporating solvent and a minor proportion of a slower evaporating solvent; the latter will impart tackiness over a longer period of time, resulting in longer assembly time.

Heat Activation

Preferred when optimum bond strengths are required as soon after assembly as possible, and where escape of volatile material is difficult or impossible. Adhesives are tacky because they are so compounded; or are tackier with solvent present than without; or become tackier with heat than at room temperature. Heat reactivation takes advantage of the latter property. If maximum strength is desired, inherently tacky products generally are not satisfactory because they have a tendency to flow under stress. Where traces of solvent are undesirable because of blistering, inadequate strength, or impossibility of losing solvent, heat reactivation can be most desirable. Parts to be bonded are cleaned, coated and dried until practically free of volatile solvent, then heated until the adhesive becomes tacky enough to adhere to another adhesive coat. Parts then are assembled and pressure applied until the adhesive cools to the point where the bond is strong enough to hold the assembly together. Assemblies so combined are usually at maximum strength as soon as the adhesive has cooled, although there are exceptions where chemical changes take place on aging. This method results in a significant advantage in that the parts can be handled—machined if necessary—as soon as assembled.

CURING METHODS
PRESSURE APPLICATION

Dead Loading, Clamps and Wedges

Unit pressures by deadloading—shot bags or sand bags applied directly to the bonding area—are of a low order, and dead-loading is possible only on flat work. C-clamps, yoke clamps, bolted jigs, and jacks have been widely used. Pressure distribution and "follow-up" may be supplied by the adherends, as in the bonding of wood or cork, but bonding of rigid materials may require chipboard or other material between the bearing surface and the work, and follow-up may be obtained from springs. Wedges are also used.

Cylinders and Hydraulic Presses

Hydraulic presses and cylinders, and air cylinders, provide excellent follow-up pressure. Applied pressures are known, readily measured, and controlled pressures of a high order can be obtained. However, with very large areas total pressure requirements may be so high that practical limitations on the size of cylinders and fixtures may militate against their use. Pressure distribution pads usually are required.

Hydraulic Pads

Hydraulic pads have been made by seam welding two flat sheets of thin, flexible metal, equipped with an inlet for oil or other fluid medium under pressure which can be used to exert hydraulic pressure; they provide good pressure distribution and "follow-up." Similar tools have been made utilizing a fire hose or a heavy rubber tube for exerting air pressure—primarily on long flat seams. Both the hose and work are restricted by rigid retaining fixtures. Rubber tubes with suitable mandrels and gaskets for retention of air pressure have been used inside metal tubes, which in turn have been restricted by heated metal fixtures. Excellent conformation to the work is obtained.

Autoclaves and Vacuum Bags

Steam autoclaves, which simultaneously apply heat and pressure, have been adapted to adhesive bonding. Work may be enclosed in a rubber bag to prevent moisture from entering the joint. Rubber bags have also been used in bonding relatively large areas with smooth surfaces by retaining the assembly between heavy forms and exerting pressure with air. Vacuum bags are widely used, particularly where oven heating is desired. The assembly is placed on a suitable cart, a rubber sheet taped over the assembly, a vacuum drawn, and the whole wheeled into an oven. Vacuum techniques not only afford an advantage in tooling cost, but also serve to withdraw volatile reaction products sometimes given off by the cure of the adhesive. Atmospheric pressure is the limit obtained by vacuum alone. However, adhesives requiring higher unit pressures may be used if suitable pressure bars are placed over the joint; a T-bar with a 1-inch face over the joint and a 4-inch face presented to the vacuum bag, for instance, multiplies the pressure by four.

Table 11—Bonding and Assembly Methods (Continued)

HEATING METHODS

Oven Heating

Oven heating of assemblies is quite common, even though heat transfer is relatively slow and long curing cycles may be involved. The method is adaptable to most of the pressure means previously described. Forced circulation in an oven is a requirement to insure uniform temperature throughout. Ovens may be gas-fired, oil-fired, electrically heated, steam-heated, or heated with infrared. With infrared units the air need not be warmed, since the work heats by direct absorption of infrared rays. Rate of heating, however, depends on color of the object; a black object heats faster than white or metallic-finished objects. Infrared heat, compared to convection, may reduce the time required to reach curing temperatures, and may be of value where spot heating in certain areas is desired.

Steam, Hot Water and Oil

Oil baths, hot water and steam afford advantages in heat transfer rate. The liquids heat by conduction rather than convection, and steam yields its latent heat on condensation. Properly clamped assemblies dipped by conveyor in hot oil baths have been cured as much as ten times faster than possible in ovens. Steam is commonly used in flat platen presses. It offers the advantage of fast temperature rise, of particular value in bonding assemblies which must be cooled under pressure with cooling effected by circulating water.

Electric Resistance

Electric resistance heating is common with platen presses and special fixtures. By passing current through a strip of metal placed either in the bond or adjacent to the bond, heat can also be applied directly where it is desired; uniformity of heating, however, is difficult to control by this means. The amount of metal exposed at the ends of the joint should be a minimum, and the cross section of the heating strip should be uniform in width to minimize hot spots.

Dielectric and Induction

High-frequency, or dielectric, heating has been successful with nonconductors of electricity, such as wood or cork. The high-frequency generator is connected to either side of an assembly, with the current running across the adhesive joint, rather than through the length of an assembly. The high frequency current generates heat in the adhesive by molecular motion. Heating is very rapid, is controllable, and the heat is introduced exactly where it is needed. Induction heating performs in a similar manner. It is adaptable to metals rather than nonmetals.

such that chemical cleaning could cause deterioration of part of the assembly. Metal parts often are painted or partially painted in all areas other than the bonding areas. In such instances mechanical cleaning is a necessity. Satisfactory bonds have been made to surfaces that have been abraded by sanding, grinding, wire brushing, or rubbing with steel wool. Such surfaces should be washed with solvent after abrading to remove grease and dust.

Chemical cleaning procedures vary with the type of metal, and the methods in TABLE 11 are offered only as typical procedures. They are not necessarily the only satisfactory methods that can be used.

Application of Adhesives: Methods used to apply adhesives or sealers vary with the nature of the surface, its dimensions and contours, and the consistency and physical properties of the liquid adhesive. Essential requirements for any method are:

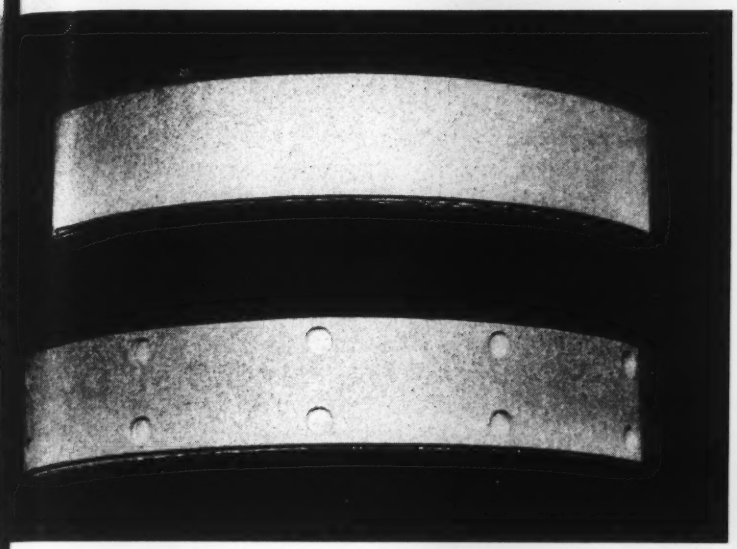
1. Proper film thickness must be applied
2. Adhesive should be applied to bonding area with minimum waste
3. Adhesive should be applied at a speed correlated with other operations involved.

Means of application may be limited by the properties of the liquid adhesive, although many adhesives are supplied at a consistency suitable for two or more methods.

Assembly and Curing: Basically, assembly with adhesives involves placing cleaned and coated parts in juxtaposition, bringing the faying surfaces and adhesives in intimate contact, and establishing a bond of the desired physical properties. Techniques for doing this depend on the materials involved, their shape, and the properties of the adhesive. It is good practice to apply the adhesive to the work as soon after cleaning as practical to minimize further surface contamination. This procedure is feasible only when characteristics of the adhesive and the bonding process permit.

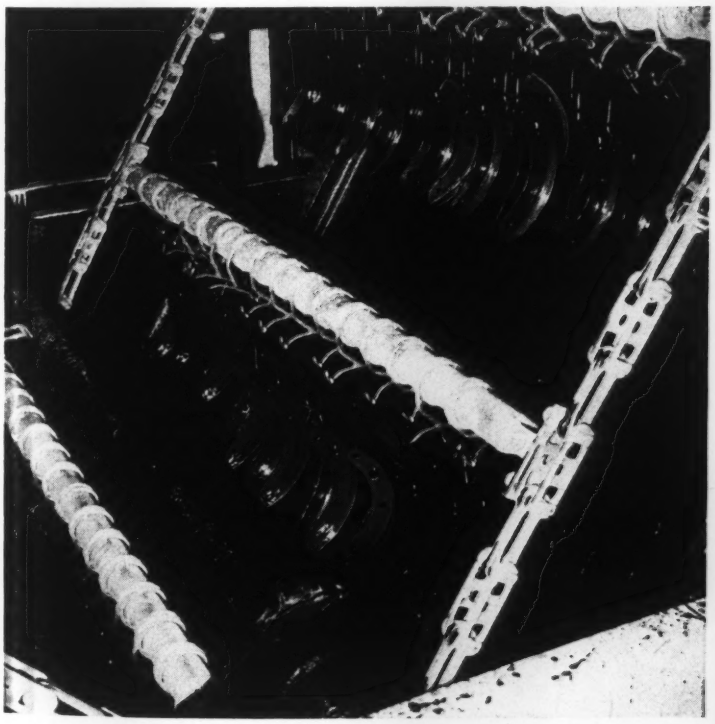
Curing an adhesive bond usually requires retention of pressure on the assembled joint during the time the adhesive is setting. With adhesives that set at room temperature, application of pressure is at room temperature. Thermosetting adhesives, requiring heat to be converted, involve the simultaneous application of both heat and pressure.

Pressure is necessary to establish good bonds—to hold the adherends in fixed relative position while the adhesive is being set; it makes possible uniform, complete contact between the adherends and adhesive; and it assists in obtaining a uniform film thickness for optimum properties. Pressure may be applied to an assembly in several ways depending on nature of the adhesive, design of the part, and its size. The most suitable methods have three features in common: (1) the amount of pressure should be adequate; (2) pressure should be retained at a constant level; and (3) it should be distributed uniformly over the work. Amount of pressure considered adequate varies with the type of adhesive and nature of the assembly, but in general it is enough pressure for uniform contact. Parts to be bonded may be warped. Where



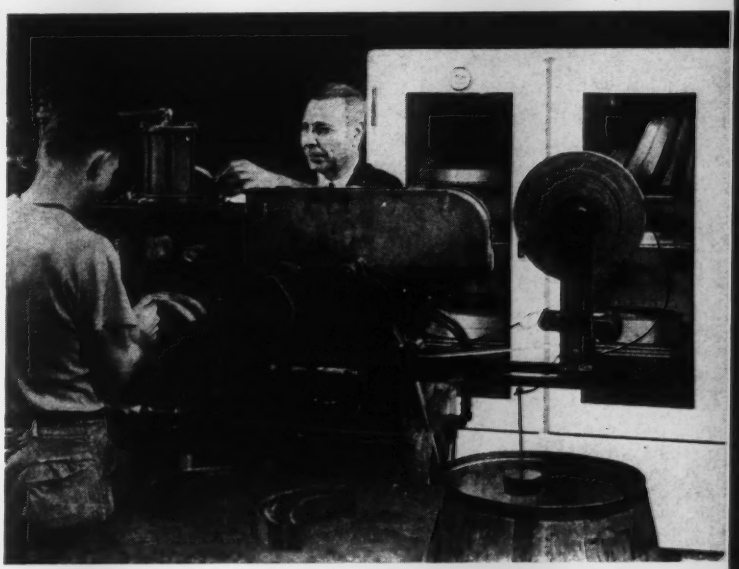
Photos, courtesy Chevrolet-Detroit Gear and Axle Div., General Motors Corp.

BRAKE SHOES of the newer bonded type and older riveted type are shown. Adhesive is a resin bonding tape which withstands a shear load of 16,000 psi without separation at the bond.



Brake shoes are first washed and pickled for cleaning, and are then immersed in a varnish dip and dried.

Brake bands receive a coat of varnish on the concave side. Bonding strips are automatically separated from paper lining, cut to length and laid on the concave face. Bonding strip coils are stored in a refrigerator for temperature contol.



Assembly for bonding is completed on a conveyor line; the brake band is first placed inside a pressure band and against the brake shoe. Pressure springs are then positioned, and a "needle" is driven home. The assembly is then baked, excess bonding material is milled off, and shoes are ground on the face.

thinner films are desired, increased pressures may be necessary. Some adhesives liberate gaseous reaction products during cure; pressures with such adhesives must be adequate to prevent the assembly from blowing apart.

For a pressure device to be satisfactory, it must retain the pressure at a reasonably constant level during the curing period, because changes take place during curing which can effectively reduce the applied pressure. Most adhesives flow under pressure, particularly at elevated temperatures. By flowing, the overall thickness of the joint may be reduced and the pressure lowered. Pressure must "follow up" such reduction in thickness. Pressure devices which may hold very tightly at room temperatures may loosen and reduce pressure on the joint at elevated temperatures, due to thermal expansion of the parts. Again, some followup is required.

Uniform distribution of pressure is most important, and at times quite difficult. High and low pressure spots within an assembly can result in lack of uniform contact, and differing film thickness which may result in variability of bond strength. With rigid fixtures or dies, a "pressure pad" like chipboard, rubber-fabric compounds or glass cloth may have to be interposed between the face of the fixture and the work to equalize pressure. Assemblies bonded in vacuum bags or autoclaves, with the pressure applied directly to the bond and not through fixtures, have excellent pressure distribution.

Heat is also required for many thermosetting adhesives to obtain a suitable bond; simultaneous application of heat and pressure is usually necessary. Many methods have been devised for the application of heat to assemblies, and some devices have been investigated for applying heat directly to the adhesive line. The time requirement specified by the adhesive manufacturer for curing adhesives at a given temperature apply only after the adhesive line has reached the specified temperature. It does not include the time required for the work to reach that temperature.

DESIGN OF ADHESIVE JOINTS

To derive maximum benefits from the good properties of adhesives, and to minimize shortcomings or weak points, joints to be bonded must be designed properly. Although acceptable assemblies have been made in spite of being designed for other methods of fastening, and adhesives have performed satisfactorily under improper design made necessary by other considerations, certainly best performance may be expected in assemblies especially designed for bonding. Size and shape of a part to be bonded are determined by the end use. Often other design considerations may not allow most effective joint design, but for maximum effectiveness and success the joints should be designed to:

1. Minimize stress on the adhesive.
2. Stress the adhesive in the direction of its maximum strength.
3. Minimize stress in the direction the adhesive is weakest.
4. Make the maximum proportion of bonded area contribute to strength.
5. Maintain continuity of bond.
6. Be adaptable to production techniques.

Behavior of an adhesive under stress conditions indicates the desirability of certain features in joint design, and the undesirability of others. Specific strength values obtained with test specimens of a given area of bond and geometry of

Fig. 1—Below—Effect of tension stresses

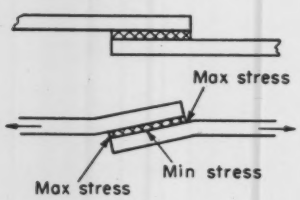


Fig. 2 — Right — Relationship between failure load and overlap for joint of *Fig.* 1

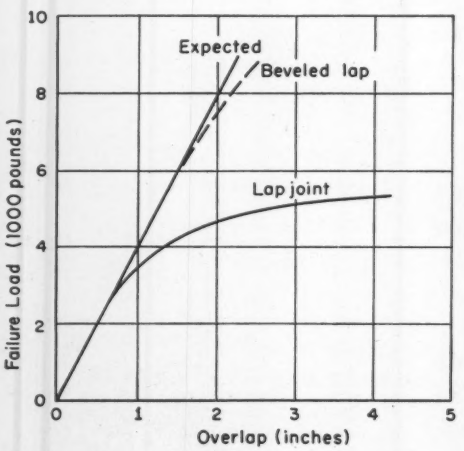
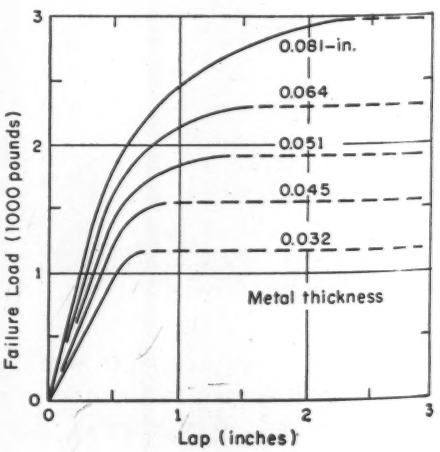


Fig. 3—Extreme right—Interrelation of failure loads, depth of lap and metal thickness for lap joints with a specific adhesive and metal



bond cannot be translated readily to other geometries or areas or materials. Strength of an adhesive under short-time loading gives no indication of performance of the adhesive under continuous stress. Strength of an adhesive as determined shortly after the bond is made is no indication of strength after exposure of the bond to aging or environmental conditions. Thus, in designing, consideration must be given to the strength of the adhesive under the stress conditions and environmental conditions to be encountered, and actual parts must be tested. Also, apparent strength of joints made under what may be considered identical conditions varies over a relatively wide range, so statistical analyses of strength may be required before an efficient design can be produced. The elastic constants of adhesives are generally unknown, and while they would be of great value to the design engineer, he usually must proceed without such information. It becomes obvious that the knowledge about adhesives as materials of construction is not as extensive as for other materials.

Metal-to-Metal Joints: Major factors influencing the choice of design of a metal-to-metal joint are duration, magnitude and direction of the load to be applied to the joint. Since most of the adhesives used for bonding metal to metal structurally are relatively rigid, strong in shear and weak in peel or cleavage, joints usually are designed to place the adhesive in shear and prevent or minimize peel or cleavage stresses. Flat plates or sheets are rarely bonded to place the adhesive in tension, although heavy sections or blocks certainly could be designed in tension when cleavage stresses can be minimized. Magnitude of shear stresses influences the area of the bond required and, where maximum stresses are involved, influences the geometry of the joint.

The most common method of assembling flat plates or sheets is through the use of the straight lap shear joint, *Fig.* 1. With the metal in tension under stress and the adhesive presumably in shear, there is a tendency for the edges of the lap to deflect, since the stress in the sheet where it enters the joint is at a maximum and decreases to little or nothing at the end of the sheet at the other edge of the joint. This deflection places the adhesive at the edges of the lap under tension stress, tending to peel the bond apart. As a consequence, observed failure loads on metals which can deform in this manner are substantially below the true strength of the adhesive. A high proportion of the failure load in lap joints is carried by the edges of the lap, illustrated by the fact that an adhesive, showing an apparent bond strength of 3000 psi with a 1-inch overlap, will fail at about 2500 pounds when only the edges of the lap are bonded with a ¼-inch stripe of adhesive on each edge. The interior ½-inch portion of the lap contributes only about one-sixth of the total strength of a 1-inch overlap in this particular case. For this reason, it is quite important that edges of lap joints be well bonded with good contact. The center portion of the overlap assumes lesser importance.

Strength of a lap joint in shear (with the metal in tension) is directly proportional to the width of the joint. For example, with depth of lap and gage of metal constant, a joint 2 inches wide will be twice as strong as a joint 1 inch wide. So the strength of a bond may be increased by increasing the width of the lap. Strength also may be increased by increasing the depth of the overlap but, unfortunately, the relationship is not linear. Since the edges of the lap carry a relatively high proportion of the load and the interior area of the bond carries a lesser proportion, it is evident that the unit strength realized as overlap increases will gradually become lower. Eventually a depth of lap should be reached beyond which no further increase in strength could be expected. A typical relationship between failure load and overlap is illustrated in *Fig.* 2, compared with the failure loads which might be expected if the relationship were linear. No significance should be ascribed to the failure loads on an absolute basis, since these will be different for each adhesive and for each gage and type of metal bonded, but the general shape of the curve is important. Evidently, the law of diminishing returns sets in, and a depth of lap is finally reached beyond which the strength of the joint cannot be increased. If greater strength is desired than may be obtained at the practical lap depths and widths, the designer may resort to a change in the gage of metal. He also may change the design to a more efficient joint.

The strength of a lap joint depends not only on the depth of lap, but also on the thickness of metal and yield strength of the metal. With adhesives which may exhibit a tensile-shear strength of several thousand psi, the yield strength of thin-gage metals is exceeded at relatively short overlaps. Since yield strength depends on the modulus and thickness of metal, and varies from metal to metal, the lap required to exceed the yield strength—which is the maximum strength one may expect to obtain—will vary with the thickness and type of metal. This fact holds true up to the point where the thickness of metal is such that the strength of the metal cannot be equalized by the apparent

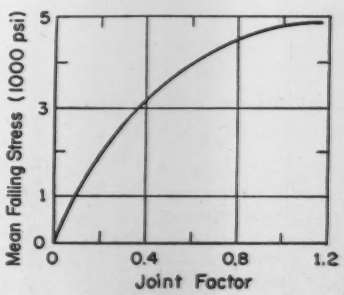


Fig. 4—Joint factor, ratio of square root of the adhesive overlap, relates these factors to failing stress in the joint

strength of the adhesive at any overlap. The interrelationship among failure loads, depth of lap, and thickness of metal for a specific adhesive with a specific metal is shown in *Fig.* 3. Curves may vary somewhat with other adhesives, so the failure loads have no significance to the designer other than to illustrate the relationship.

It should be possible to relate thickness and overlap to failing stress. This has been done with a "joint factor," which is the ratio of the square root of the thickness to the overlap. A uniform curve is obtained, *Fig.* 4, when joint factors obtained with steel, clad aluminum and aluminum alloy with several different overlaps are plotted against the mean failing stress. At high values of the joint factor, the failing stress approaches asymptotically a value which is characteristic of the adhesive. Thus, a small overlap shows a high apparent failing stress approximating the true failing stress or strength of the adhesive. The approximately linear relationship between a joint factor of zero and about 0.3 indicates that the apparent failing stress is proportional to the joint factor, and the failing load is independent of the overlap and proportional to the square root of the thickness. For other metals and other adhesives, variation of strength with joint dimensions would not necessarily be the same. Such information is not generally available from adhesive suppliers. Since the strength of a joint depends on the thickness of the metal and the elastic constants of the metal, the designer can adjust depth of lap and gage of metal to obtain, within limits, a desired strength.

Strength of lap and other types of joints depends also on the thickness of the adhesive film, which may be characteristic for each product. Although it is commonly believed that the strongest joints are made with the thinnest films of adhesives, actually optimum film thicknesses can exist. This fact is evidenced by the well-known reduction in strength which occurs with heavy film thicknesses of adhesive, and the poor bond strengths obtained with "starved" joints. Before a decision can be reached on the optimum film thickness desired, consideration must be given to the type of stress the joint must withstand. Difficulties from creep may

Fig. 5 — Metal-to-metal joints for flat plates

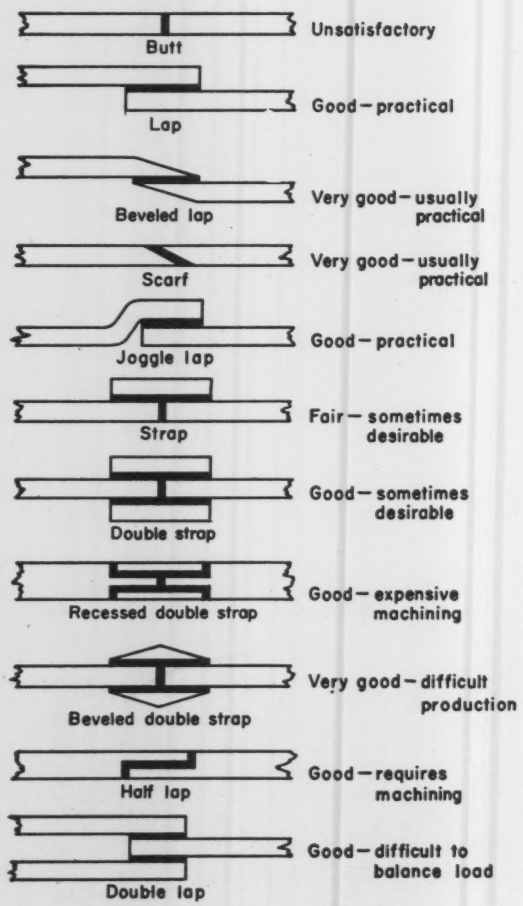


Fig. 6—Methods of avoiding peel stresses on rigid adhesives

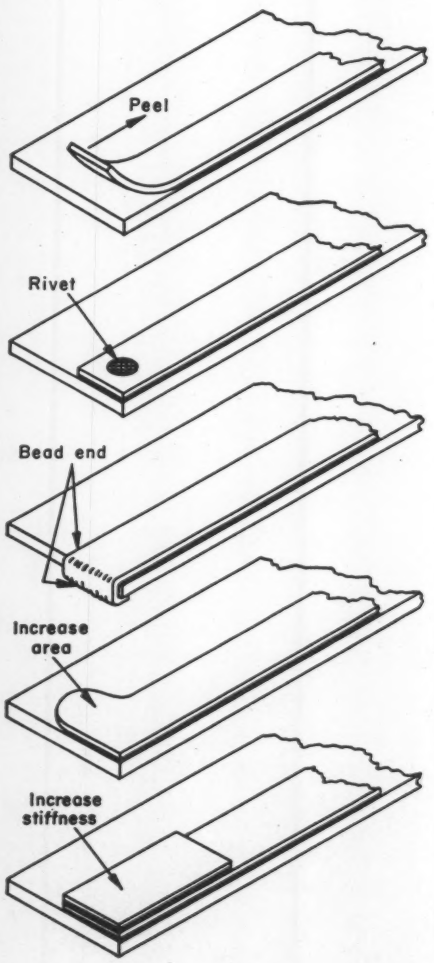
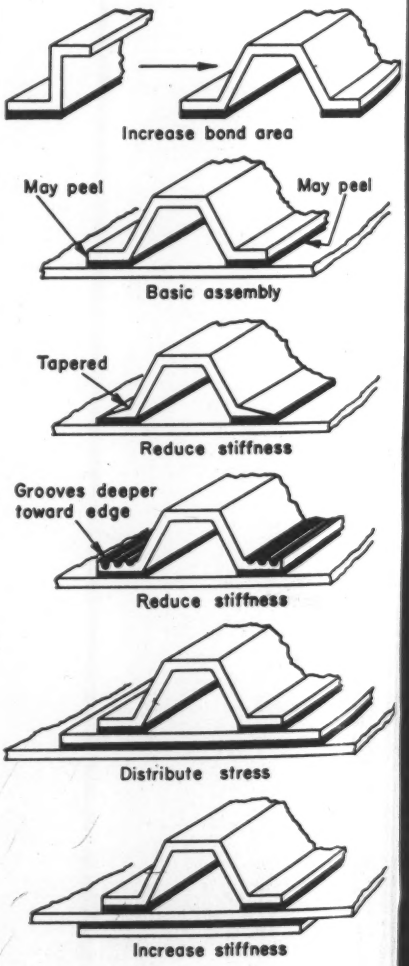


Fig. 7—How to avoid peel by changing stiffness of either the base sheet or the flange



be greater with thicker adhesive films. Relatively thin adhesive films may show the highest shear strength, and heavier film thicknesses may improve impact and peel properties. Therefore, faying surfaces must be free of grooves, slots and waviness, and protuberances or bosses that may interfere with attainment of the optimum film thickness.

Strength properties of lap joints in thin metals may be improved through the judicious supplementary use of rivets as well as adhesive. Improvements in shear strength, impact, deflection, permanent set, and fatigue properties may be realized. Rivets may also be useful in preventing peel from starting in joints. The combination of rivets and adhesive, however, must be evaluated for the specific assembly. Limited experience has shown in some instances that weaker assemblies can result from such a combination.

A variety of joint designs have been proposed. Some are illustrated in *Fig.* 5 which can be of value in specific design problems. The scarf joint is the most efficient. It affords uniform stress distribution over the entire bonded area, and eliminates the stress concentrations found in the lap joint. The beveled lap also demonstrates good stress distribution. Examination of *Fig.* 2 reveals the advantages strength-wise realized from the beveled lap in comparison with the plain lap joint. However, both the beveled lap and scarf joint present problems in production. Machining operations are quite difficult with thin metal. The feather edges tear readily, and the application of bonding pressure to the beveled lap is difficult. Direction of stress application may indicate the advantages of one joint over another. For example, the double strap or recessed double strap joints offer advantages under bending stresses. Similarly, a double strap joint with plates butting can be very good in compression where some of the other joints may be weak. However, reduction in thickness of metal, such as required for half-lap or recessed strap joints, also reduces the tensile loading (shear in the adhesive) the joint can stand.

Dissimilar adherends may be bonded with a scarf joint with minimum sacrifice of uniform stress distribution if the ratio of the thicknesses is inversely proportional to Young's moduli.

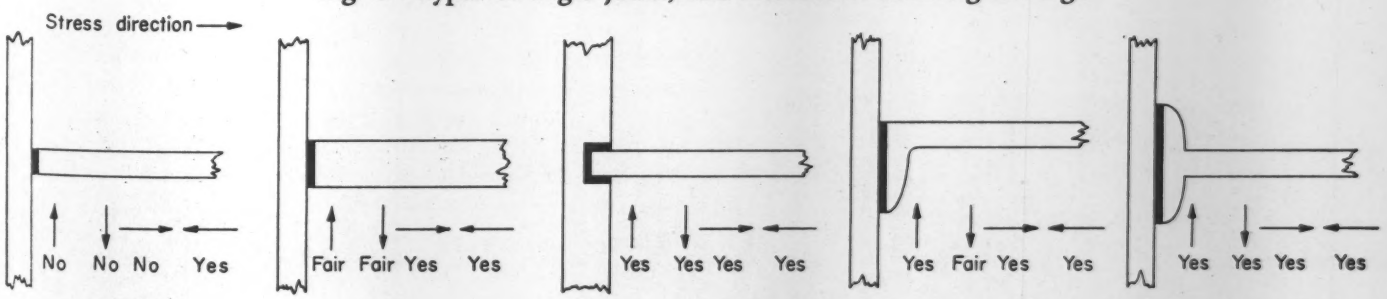
Peel stresses exerted on rigid adhesives can cause failure. Some of the structural adhesives, however, are better in this respect than others. Proper design, too, can help. *Fig.* 6 illustrates some of the steps that can be taken. In the attachment of stiffening members to thin sheets, common in aircraft construction, the sheets deflect in service and peel stresses are exerted on the adhesive. If the flanges on the stiffening section can deflect with the sheet, minimum difficulty from peel would be expected. Either increasing the stiffness of the sheet, or reducing the stiffness of the flange on the stiffening section, should result in improvement. How stiffness may be changed to minimize peel is illustrated in principle in *Fig.* 7. The sections illustrated, however, are not intended to be readily adaptable to aircraft problems, as production difficulties may exist.

In the bonding of heavy sections, parts should be designed so that the adhesive is in shear, as with flat sheets. But if the bond can be placed in pure tension, this too should be satisfactory. However, this is most difficult to arrange, since cleavage stresses usually result. Typical approaches to the reduction of cleavage are illustrated in *Fig.* 8. Angular joints, such as corners, also give rise to either peel or cleavage stresses, depending on the gage of material used. Reinforcement of corners is desirable, as in *Fig.* 9.

Butt joining of solid rods would be expected to result in generally satisfactory performance in compression, tension, and torsion if the stresses were true. However, cleavage forces are the rule rather than the exception. Better performance is obtained through the use of recessed designs such as those illustrated in *Fig.* 10.

Cylindrical or tubular joints have limited contact area unless heavy wall thicknesses are involved. Machining can provide adequate area for bonding. At the same time the strength of the joint can be improved substantially by proper design. *Fig.* 11 illustrates some of the approaches that have been made to improve joints of this type. Adequate clearance for adhesive must be allowed. Although pressure during bonding may be applied by compression from the ends, radial pressure is not practical and high solids-content, gap-filling adhesives may be required with some designs.

Fig. 8—Types of angle joints, and methods of reducing cleavage



Rigid Plastics: Design of joints for rigid plastics follows the same practice as for metals. Although some reinforced plastics of phenolic, polyester, and silicone resins have strengths comparable to metal, they are often anisotropic. Strength properties are directional, and direction of load application becomes important. Anisotropic sheets should, of course, be oriented to obtain maximum strength properties. Also, some plastics tend to delaminate through separation of one ply from the next under peeling stress at relatively low loads. Such a property needs be considered in the design of joints with laminates made from resins which do not adhere well to the reinforcing fiber. Some of the joints illustrated in *Fig.* 5, such as the plain lap and joggle lap joints, are more susceptible to delamination failure under tension (with the adhesive in shear) than a scarf joint or a beveled lap joint. The double strap joint is also useful for minimum peel stresses in tension and would be good in compression. Rigid laminates with high delamination strength and resistance to peel may be bonded with joints of the types described for metal.

Laminates with unequal moduli, or laminates to be bonded to other materials, may be joined with efficiency if thicknesses of material are used in an inverse ratio to the moduli; or if scarfs tapered according to the moduli are used.

The previous considerations are important for high-strength bonds with laminates. Many assemblies not involving any particular stress in service or residual stress from bonding can be bonded with nonstructural adhesives. Usually such joints may be of any of the types previously described.

Transparent plastics are often bonded with solvent or monomers which, through fusion and solution with the plastic or polymerization, result in bonds as strong as the plastic itself. Butt joints in flat sheets or on curved surfaces and right-angle butt joints have been successful, but it is good practice to design such joints to hold the stress on the bond to a minimum. Plastic laminates are also commonly bonded to plywood in sheet form. To maintain a sheet flat under a range of temperature and humidity conditions, it is necessary to balance the construction by bonding a plastic sheet to the back of the plywood as well as the face.

Fig. 9—Reinforcement of corners

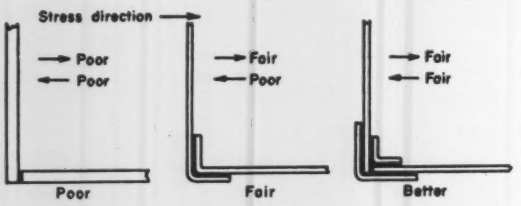
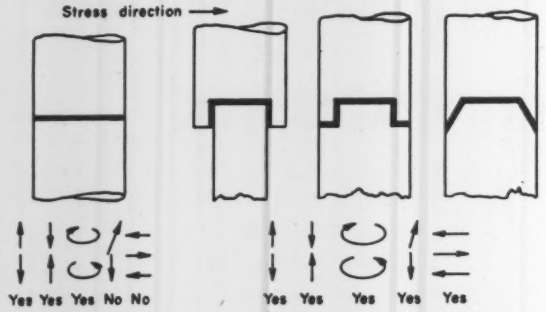


Fig. 10—Designs for end joining of solid rods



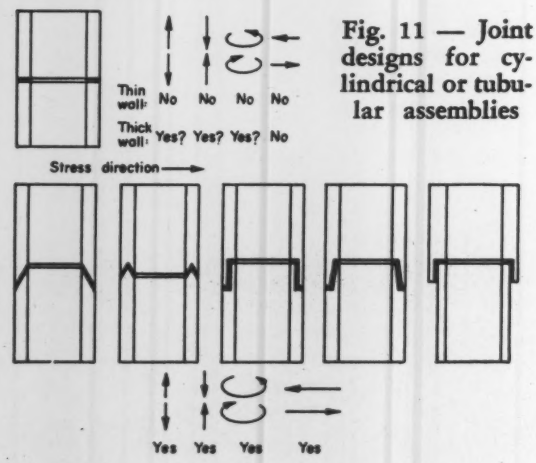


Fig. 11 — Joint designs for cylindrical or tubular assemblies

Wood Design: Wood is an anisotropic material. As such, it presents problems in gluing. Change in dimensions with moisture absorption depends on grain direction, and strength properties differ with grain direction. Tensile strength of wood perpendicular to the grain is approximately one-tenth the tensile strength in the grain direction. In the design of glued laminated members, joints usually are designed with the adhesive in shear either parallel or perpendicular to the grain, or in compression in any grain direction. Both tension and cleavage are avoided perpendicular to the grain. End-grain butt joints also are avoided.

The difference between the tangential and radial shrinkage in wood is great, in the ratio of 2 to 1, so for maximum durability similar types of lumber should be bonded together. Density of the component parts should be as nearly the same as possible. If different species are necessary, moisture expansion coefficients should be matched if possible.

End-grain butt joints are considered not glued as far as transmission of stress is concerned. They can transmit no tensile stress, and transmit compressive stresses only after considerable deformation. Joining of wood end-to-end is commonly accomplished through scarf joints. Since slope of the scarf controls the ratio of end-grain to face-grain, with steep slopes approaching end grain and long scarfs approaching flat grain, efficiency of the scarf in tension (adhesive in shear) depends on the slope. Approximate relationship of slope and efficiency compared to an unjointed member is:

Scarf Slope	Approx. Efficiency (per cent)
Flatter than 1 in 12	90
1 in 12	85
1 in 8	80
1 in 5	65

A slope of 1 in 12 is commonly used for tension members and the tension portion of bending members. Generally, slope of scarf joints in compression members should not be steeper than 1 in 5. Efficiency of plain scarf joints varies somewhat with the wood, but the differences are not significant. It is quite possible that an efficiency of 100 per cent in tension (adhesive in shear) cannot be realized at any slope no matter how flat. Scarf joints should be well distributed in multiple laminations so they do not fall adjacent.

Engineering formulas applicable to solid wood structures are also applicable to structures of laminated wood. However, curved sections of laminated wood can be made, not commonly done with solid wood. Here, engineering formulas applicable to curved beams should be used.

The plain scarf joint requires the application of lateral or transverse pressure during curing of the glue. Since long scarfs are required, some lumber is wasted. As a consequence, other joints have been designed to improve these features. Several commercial joints are illustrated in *Fig.* 12. All are less efficient than a plain scarf with a slope of 1 in 10 or flatter. The serrated joints show an efficiency of about 50 to 75 per cent in tension (adhesive in shear) parallel to the grain; the fingered joints with fingers through the face of the board about 45 per cent; Onsrud joints 25 to 35 per cent; and fingered joints with fingers through the edge of the board about 20 per cent. Efficiency of all the joints in compression approaches 100 per cent.

Edge gluing in laminated structures is considered necessary only to minimize moisture penetration and to improve appearance. Edge joints are not considered as load-bearing. Edge gluing of lumber for other purposes is, however, often the only gluing operation involved. Stresses due to seasonal changes can arise, even though no other stress may be exerted. Generally, thermosetting resin adhesives perform adequately under such circumstances. However, from a design standpoint consideration should be given to the fact that some adhesives can creep under stress, and edge-glued joints might open up. This usually can be prevented by proper choice of adhesive, or by metal fasteners at the ends of the boards.

Assembly gluing, or the fastening together of the member parts of a construction with adhesive, requires a variety of joints depending on the design of the assembly. Space allows the illustration of only a few of these in *Fig.* 13. Strongest joints are formed with parallel grain, as in face-to-face or edge-to-edge gluing, but often the bonding of end grain or grain at 90 degrees is involved.

Butt joints carry only a very small load. Butts involved in corners usually are reinforced with filler blocks. The various joints involving grain of one piece at 90 degrees to the other when tightly fitted have reasonable strength. However, most assembly joints of this nature are suitable only for interior use, since wide variations in moisture content cause the wood to swell and shrink at different rates in the different grain directions, and failure results. Dovetail joints usually are not glued. Mortise and tenon joints and doweled joints also give strong constructions when properly fitted, but under severe exposure can loosen. The loosening of dowels can be minimized through the use of a so-called "expanding" dowel, which is mechanically compressed and expands in service. Often assembly joints do not fit tightly, and the use of a gap-filling adhesive is desirable.

Wood-to-metal bonding in flat panels has been successful for many years, but brief attention should be given to some of the problems which arise when dissimilar materials are bonded together. Metal sheets bonded to one side of plywood or lumber in large panels prevent absorption of moisture from the metal side, whereas moisture has ready access to the wood side. Also,

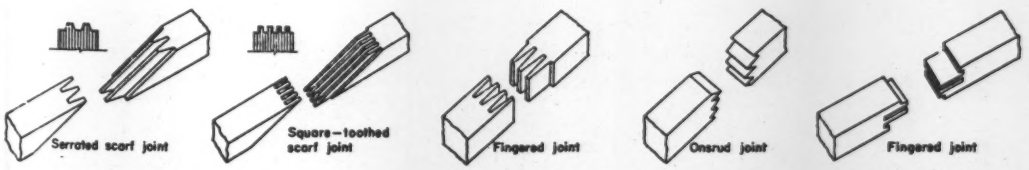


Fig. 12—Typical end joints for wood assemblies

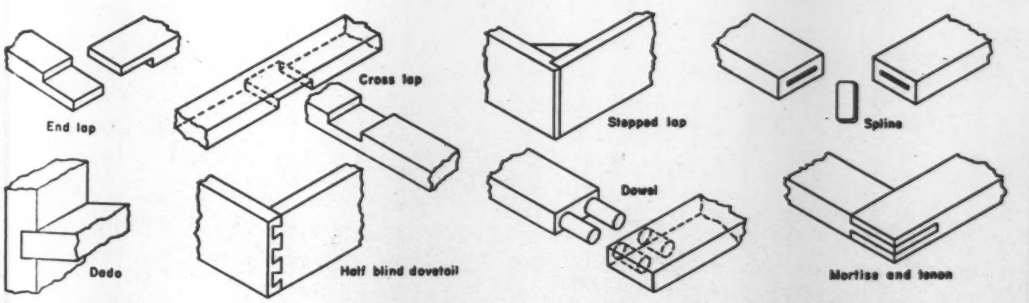


Fig. 13—A few typical assembly joints for wood constructions

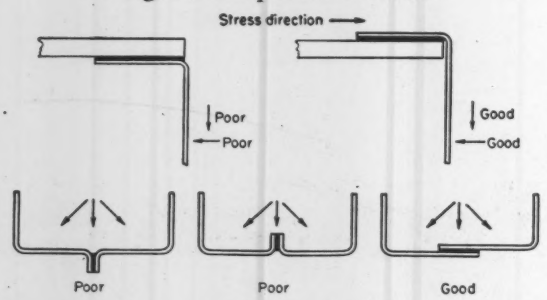
wood and metal have different thermal coefficients of expansion. So changes in temperature or moisture content can cause the panels to warp. Thus, a backing sheet of metal to balance the construction, which keeps the panels flat, is desirable. The adhesive for such applications should have some elasticity to allow for dimensional change with temperature change.

Some wood-to-metal bonding is done with heat-setting adhesives, and is satisfactory for small parts. With any substantial length or area involved, the different thermal coefficients produce warping on cooling of the parts, because the metal and wood are bonded in an unequally expanded condition. Internal stresses set up have been known to cause failure as soon as the assembly cools. Stresses may be minimized by breaking the continuity of the wood. They may also be minimized or eliminated by bonding at room temperature rather than elevated temperatures. It may be necessary to use a primer on the metal which subsequently may be cold glued to the wood with phenolic-type room-temperature setting adhesives. Or a veneer may be bonded to the metal by a hot process. The wood veneer is then bonded to the wood member with a suitable wood-to-wood adhesive.

Translation of stress from heavy metal sections to wooden members, as would be required with metal fittings, also presents problems. Adjustment of bonded area and depth to which the metal overlaps help distribute stress, and the shape of the fitting also contributes. However, the best joints probably are made with tapered fittings gradually reducing in section.

Flexible Materials: Thin rubber and plastic sheets which cannot be heat-sealed may be edge-joined by a simple lap joint, or may be butted and a strap or doubler of the same material or of cloth applied over the seam. Butting of sheets of some thickness is not practical, since butt joints in tension generally have inadequate strength. Scarf joints have been found to be most practical. The same holds true for strips of rubber in thickness ranges of $\frac{3}{16}$ to $\frac{3}{8}$-inch or heavier, which might require splicing or may require fastening to form corners, as for example, gasket assemblies. The length of a scarf joint in rubber should be at least four times the thickness; in some instances longer scarfs are required. Uniform stresses may be obtained in materials of unequal moduli of elasticity by tapering the material symmetrically over the length of the scarf joint in proportion to the modulus.

Fig. 14—Methods of joining flexible plastic or rubber



Adhesives used for bonding rubber vary widely from soft, rubbery, tacky products to rather hard, rigid thermosetting resins. Although the rubbery adhesives generally have good peel properties, joints should be designed in shear rather than in peel where possible. The same applies to flexible plastic sheets. *Fig.* 14 illustrates plastic or rubber sheet bonded to metal in shear and peel, and flexible plastic bonded to itself. In assembling sheets of thin gage to metal, particularly when bonded behind the metal as illustrated to place the adhesive in shear, overlap should be adequate to place minimum unit stress on the adhesive. Tension in the sheet during assembly should be at a minimum since it can result in residual constant stress on the adhesive.

Motor mountings and roll coverings involve the adhesion of heavier sections of rubber to metal. Basic considerations of minimizing the stress in the adhesive, designing for loads within the capacity of the assembly, and elimination of stress concentrations apply to these assemblies as well as other types that have been discussed. Size and shape of a roll, and thickness of rubber, are usually determined by the end use. Often changes in design are not possible to permit most efficient functioning of the adhesive. Under severe loading, with rubber roll coverings which allow stress to be translated through the rubber to the adhesive, failures may be minimized by improving stress distribution in the rubber next to the adhesive bond by increasing rubber hardness at the inner diameter.

Stress concentrations also should be minimized in rubber mountings though the elimination of sharp corners or elimination of those inserts in the rubber which could be fastened to the metal. The metal should be thick enough to prevent peel stresses which may occur with thin-gage metals. Sharp changes in section in the rubber can also result in stress concentrations. Loading over the capacity of the rubber-metal assembly can result not only in adhesive failures, but also in short life of the assembly due to rubber fatigue and failure. Depending on permissible cost and performance requirements, it may be possible to eliminate overstressing in some applications by providing a bumper which comes into play when a given deflection is reached. Rubber to metal assemblies in shear or tension loading may be designed at about 50 psi, and in compression at about 250 psi, although these loadings depend to a great extent on the application involved, the type of rubber, etc. Greater stability in such assemblies results when the ratio of bond area to free area of rubber is highest. Shear loading generally provides more stability than either tensile or compression loading.

analytical approach to

Compression Spring Design

By Frank A. Votta Jr.
Chief Engineer
Hunter Spring Co.
Lansdale, Pa.

A method for finding the best design when spring gradient is not fixed

DESIGN of helical compression springs may be approached along any of a number of well established paths. The particular procedure used will depend largely on the accuracy required by the application and the range of choice established as accepted design practice. Hit-and-miss spring design is frequently adequate where spring requirements are not critical and practically any spring which fits into the space will perform satisfactorily. A more orderly design procedure involves the use of spring tables in which values of spring load and deflection are related to outside diameter, wire diameter and basic stress. Another common method is based on nomographic charts or spring slide rules. Most accurate and flexible design is achieved, however, with the analytical method in which the design problem is thoroughly examined and all possible solutions, as well as the optimum solution, are obtained and considered.

When hit-and-miss methods are used, the spring attained may be workable yet far from the most economical solution for the job. Designing springs with tables or nomographs usually gives good results, but again the most economical and efficient design may not be achieved. Given the same spring design problem, two experienced designers would rarely agree on its solution by either of these methods.

Use of spring tables or nomographs requires that spring gradient, diameter, load-at-length and deflection be specified. These spring variables will lead to a workable design, such as *Fig.* 1*a*, or sometimes to an impossible combination of conditions, *Fig.* 1*b*, where the solid length, *h*, is greater than

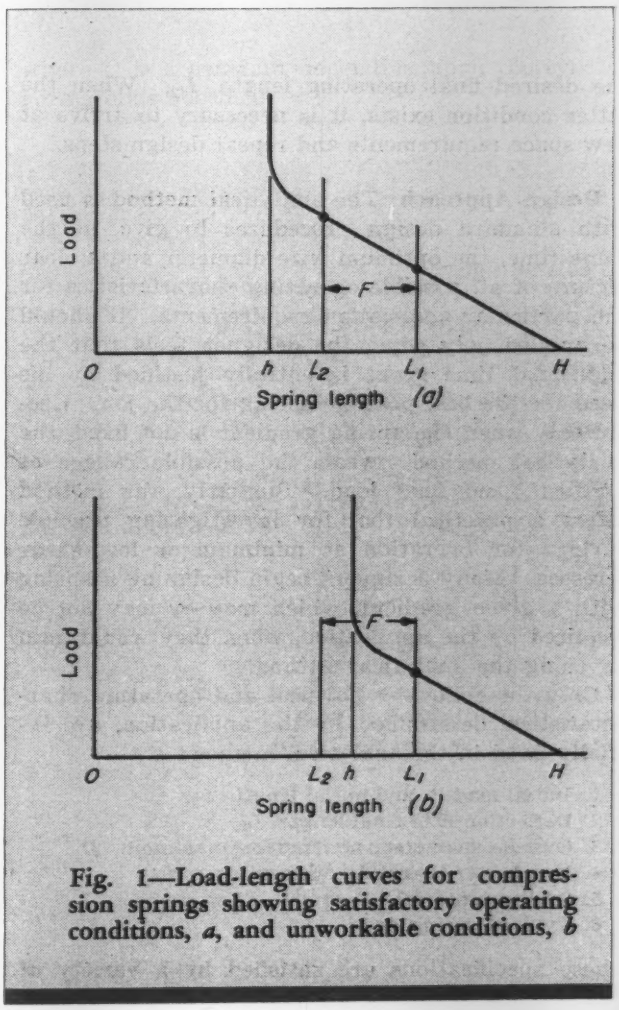


Fig. 1—Load-length curves for compression springs showing satisfactory operating conditions, *a*, and unworkable conditions, *b*

Nomenclature

A = Basic stress correction factor defined in Equation 6
C = Constant defined in Equation 2
D_c = Inside diameter of coil corrected for spreading under deflection, inches
D_m = Mean diameter of spring coil, inches
D_o = Outside diameter of spring coil, inches
d = Wire diameter, inches
d_{opt} = Optimum wire diameter defined in Equation 1, inches
F = Operating deflection of spring, inches
G = Shear modulus of elasticity, psi
H = Free length of spring, inches
h = Solid length of spring, inches
h_{nom} = Nominal value of solid length defined in Equation 1, inches
K = Spring gradient, pounds per inch
L_1, L_2 = Initial and final operating lengths of spring, respectively, inches
N = Number of active spring coils
P_1, P_2 = Initial and final spring loads, respectively, pounds
R_s = Stress range = $(P_2 - P_1)/P_2$
R_1 = Wahl stress concentration factor, round wire in shear, for spring index D_m/d
s_b = Basic stress defined in Equation 6, psi
s_s = Maximum allowable shear stress, psi
s_1, s_2 = Initial and final operating wire stresses, psi

the desired final operating length, L_2. When the latter condition exists, it is necessary to arrive at new space requirements and repeat design steps.

Design Approach: The analytical method is used with standard design procedures to give, at the same time, the optimum wire diameter and a clear picture of all possible operating characteristics for the particular application requirements. It should be applied only when the designer feels that the additional time spent is entirely justified by his need for the best possible spring for the job. Useful only when the spring gradient is not fixed, the analytical method reveals the possible ranges of gradient, and final load. Similarly, the method offers a practical tool for investigating possible springs for operation at minimum or low shear stresses. Many designers begin designing a spring with a given gradient, which may or may not be required by the application, when they would gain by using the analytical method.

Only the following physical and operating characteristics, determined by the application, are initially fixed in the analytical method:

1. Initial load P_1 and initial length, L_1.
2. Deflection F to final length, L_2.
3. Outside diameter, nominal or maximum, D_o.
4. Number of operating cycles.
5. Spring material.
6. Type of spring ends.

These specifications are satisfied by a variety of compression springs represented in *Fig.* 2 by load-length curves with different values of final load P_2, gradient K and free length H. Since spring length at final load is $L_2 = L_1 - F$, a nominal value of solid length h_{nom} is easily determined as an estimated maximum in relation to L_2. For a given outside diameter of the spring, the only independent variable in the analytical method is wire diameter.

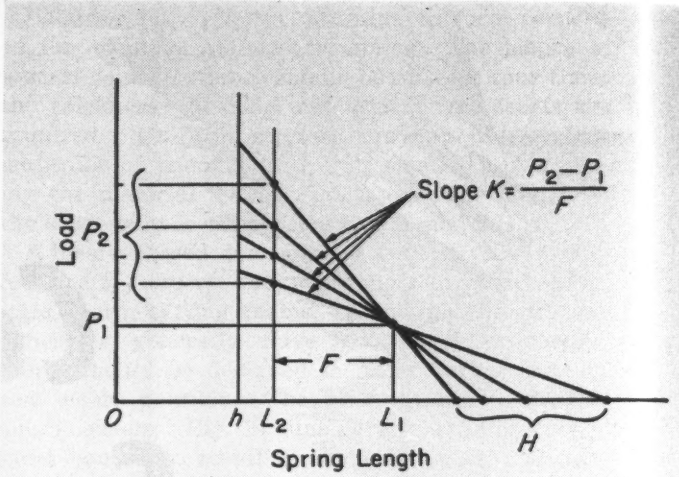


Fig. 2—Family of load-length curves for several compression spring designs which have different wire diameters but satisfy the same specifications for initial lengths (L_1) and load (P_1), and deflection (F)

Stress and Wire Diameter: Because P_2, K and H are all represented by, and calculated from, the value of final stress, s_2, for different wire diameters, the foremost consideration is how final stress influences wire diameter for given initial specifications. The final stress is the maximum shear stress which the spring material sustains in operation and can be both too high, resulting in permanent deformation, or too low, indicating an uneconomical use of material.

In *Fig.* 3, the solid curve illustrates how final stress, s_2, varies with wire diameter, all other spring characteristics remaining constant. Using the calculated values of final stress, P_2, K and even H may also be plotted as functions of wire diameter. It is evident that there is a minimum final stress s_{2min} corresponding to an optimum wire diameter, d_{opt}. The magnitudes of the co-ordinates s_{2min} and d_{opt} on *Fig.* 3 may be calculated for specified values of P_1, h, F, G and D_c (outside diameter minus an allowance for wire diameter and coil spreading with deflection). The dotted curves on *Fig.* 3 represent final stress versus wire diameter for progressively smaller values of D_o, while all other characteristics are constant. As D_o decreases it is evident that d_{opt} becomes smaller while s_{2min} increases.

It is not always possible to design a compression spring having all the desired physical and operating characteristics. The minimum final stress, s_{2min},

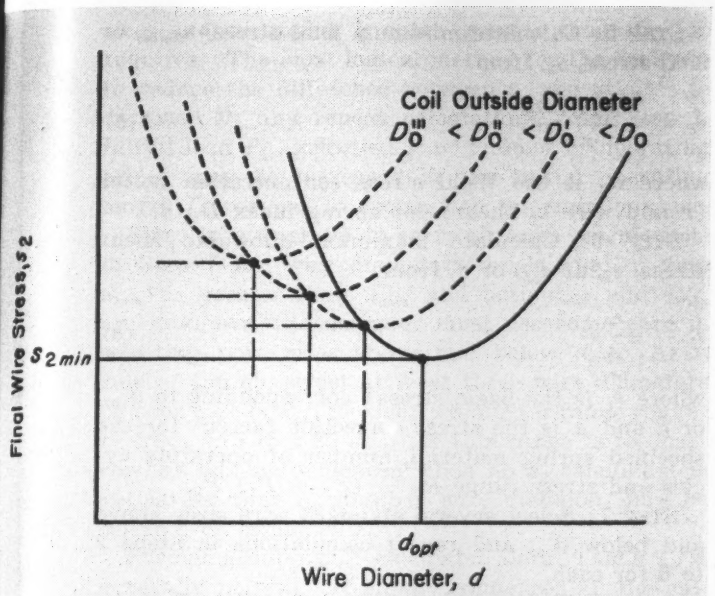


Fig. 3—Effect of wire diameter on final stress, all other spring characteristics remaining constant. Each curve represents a specific outside coil diameter, the curves progressively shifting to the left as the diameter decreases

for given values of P_1, F and D_o may exceed the maximum allowable shear stress s_s at d_{opt}. Thus, the final stress at any wire diameter is greater than the maximum allowable stress and it is impossible to design a spring with the required fatigue life. This condition is illustrated in *Fig.* 4 where two curves for s_s versus wire diameter are superposed on a plot of s_2 versus wire diameter, as in *Fig.* 3. The lower s_s curve represents specified requirements on fatigue life and stress range which cannot be met by the spring with the characteristics of the solid s_2 curve. The best possible spring under these conditions would probably have the wire diameter d_x, since the difference between actual and permissible final stress is smallest at this point, but the spring is still overstressed.

The upper s_s curve in *Fig.* 4 corresponds, for example, to a shorter specified operating life for which higher stresses are permissible. There is now a range of wire diameters—a number of possible spring designs—for which s_s exceeds s_2 and all specifications are satisfied. The diameters d_{min} and d_{max} represent the minimum and maximum possible wire sizes, respectively, under these particular conditions. The longer operating life represented by the lower s_s curve could be maintained by increasing the spring D_o in a larger working space, resulting in the new, dotted s_2 curve in *Fig.* 4. There is then a useful range of diameter selection, the designer perhaps deciding to specify d_{opt}. Final stress could also be reduced below the maximum allowable by reducing either or both P_1 and F or by increasing L_1.

Design Procedure: With the analytical method, the designer can obtain an accurate graphical design tool, *Fig.* 5, which represents all possible springs satisfying the initial specifications. The best possible wire diameter, which may or may not be d_{opt}, is used in a conventional design procedure to calculate other spring characteristics.

The following nine steps comprise the analytical method of compression spring design in a logical, easy-to-apply sequence:

STEP 1: Calculate optimum wire diameter, d_{opt}, from

$$d_{opt} = \left(\frac{12\,P_1\,D_m^3\,h_{nom}}{G\,F} \right)^{1/5} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $h_{nom} = 0.85L_2 = 0.85\ (L_1 - F)$, a value which allows a 15 per cent margin between final length and the largest possible solid length. Mean coil diameter, D_m, is obtained from the specified D_o by assuming an approximate wire diameter d where $D_m = D_o - d$. Some error is introduced here since the wire diameter must be assumed. However since the calculated d_{opt} is not used for actual calculations in plotting the curves, the error for all practical purposes, has no effect.

STEP 2: Calculate number of active coils, N, from

$$N = \frac{h_{nom}}{d} - C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where C is a constant depending upon the type of spring ends specified.

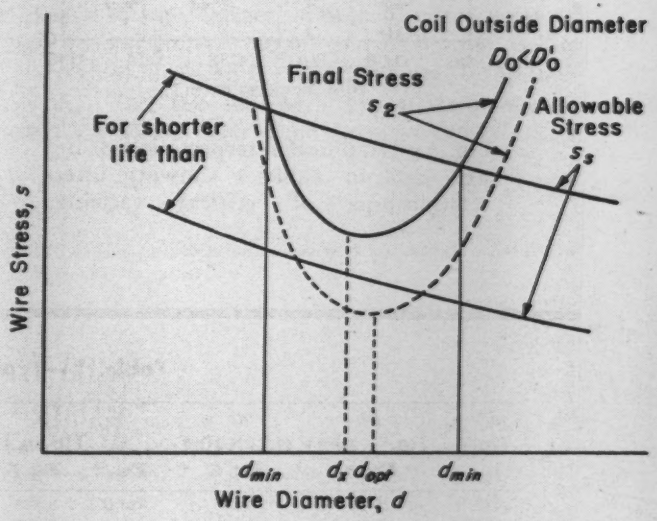


Fig. 4 — Allowable stress curves superposed on actual working stress curves for comparison and analysis of two spring designs with different outside coil diameters

STEP 3: Calculate spring gradient, K, from

$$K = \frac{Gd^4}{8\,D_m{}^3N} \quad \ldots\ldots (3)$$

where $D_m = D_o - d$ and d is d_{opt} or the particular wire diameter selected.

STEP 4: Calculate final load, P_2, from

$$P_2 = P_1 + KF \quad \ldots\ldots (4)$$

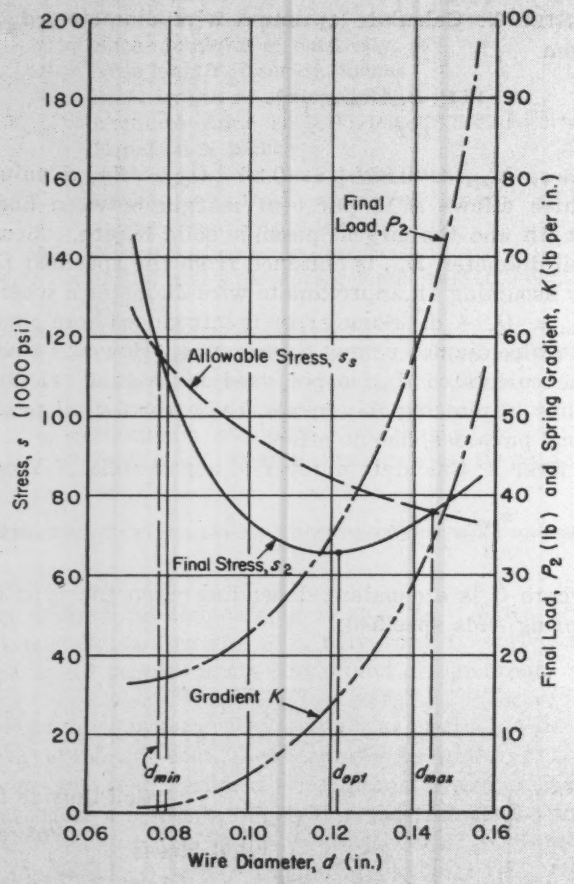


Fig. 5—Graphical interpretation of design data in Table 1 showing interrelationships of critical variables

STEP 5: Calculate minimum final stress, s_{2min}, or final stress, s_2, from

$$s_2 = \frac{8\,P_2\,R_1\,D_m}{\pi\,d^3} \quad \ldots\ldots (5)$$

where R_1 is the Wahl stress concentration factor (round wire in shear) for spring index D_m/d.

STEP 6: Calculate maximum allowable shear stress, s_s, at d_{opt} or d, from

$$s_s = \frac{s_b}{A} \quad \ldots\ldots (6)$$

where s_b is the basic stress* corresponding to d_{opt}, or d and A is the stress correction factor* for the specified spring material, number of operating cycles and stress range $R_s = (P_2 - P_1)/P_2$.

STEP 7: Select several standard wire sizes above and below d_{opt} and repeat calculations in Steps 2 to 6 for each.

STEP 8: Plot the data calculated in Step 7.

STEP 9: Select the best possible wire diameter based on review of the graph and complete the spring design.

Before proceeding any further than Step 6, the designer must be certain that s_s at d_{opt} calculated in Step 6 exceeds s_{2min} in Step 5. If s_s is smaller than s_{2min}, there are five practical, but not always possible, courses of action:

1. Increase D_o by providing more working space.
2. Reduce deflection F.
3. Reduce initial load P_1.
4. Increase initial length L_1 to increase h_{nom}.
5. Reduce number of operating cycles.

Following one or more of these courses of action, the designer then repeats the previous procedure from Step 1 until a d_{opt} is calculated for which s_s is greater than s_{2min}.

As s_s increases above s_{2min}, the number of possible wire diameters between d_{min} and d_{max}, *Fig.* 4, becomes larger. Although it is useful to have a good selection of possible wire diameters, too great a difference between s_s and s_{2min}, or between d_{min} and d_{max}, means that the spring selected is uneconomical, usually offering unnecessarily large wire

*O. G. Meyers—"Working Stresses for Helical Springs," MACHINE DESIGN, Vol. 23, No. 11, November 1951, Page 135.

Table 1—Typical Design Calculations

d* (in.)	d^4 (in.$^4\times10^{-6}$) Eq. 3	d^3 (in.$^3\times10^{-4}$) Eq. 5	N Eq. 2	K (lb/in.) Eq. 3	P_2 (lb) Eq. 4	D_m/d	R_1 Eq. 5	s_2 (psi) Eq. 5	R_s	A Eq. 6	s_b (psi) Eq. 6	s_s (psi) Eq. 6	H§ (in.)
.072	26.87	3.73	28.0	0.849	16.28	16.35	1.085	142,000	.0787	.96	120,000	125,000	21.65
.080	40.96	5.12	25.0	1.469	17.20	14.62	1.098	109,900	.1280	1.02	117,000	114,600	14.21
.0915	70.09	7.66	21.7	2.995	19.50	12.65	1.114	83,500	.231	1.12	115,000	102,700	9.01
.0937	77.08	8.23	21.1	3.41	20.11	12.32	1.117	80,600	.254	1.14	113,000	99,100	8.40
.1055	123.9	11.74	18.6	6.38	24.56	10.85	1.134	69,100	.390	1.20	111,000	92,500	6.35
.1205‡	210.8	17.50	16.1	13.10	34.60	9.38	1.155	65,700	.566	1.30	110,000	84,600	5.15
.135	332.2	24.60	14.2	24.3	51.40	8.26	1.178	72,100	.709	1.36	108,000	79,500	4.62
.148	479.8	32.42	12.6	40.8	76.30	7.45	1.190	78,700	.804	1.40	105,000	75,000	4.37
.156	592.2	37.96	12.1	53.6	95.50	7.01	1.212	85,100	.843	1.42	104,000	73,300	4.28

*Standard wire sizes. ‡Values actually calculated for assumed value of d_{opt} = 0.1206-inch. §$H = L_1 + (P_1/K)$.

sizes and occupying a space greater than the job requires. The most logical method for the designer to reduce the difference between s_s and s_{2min} is to decrease D_o and repeat calculations from Step 1. Initial load P_1, deflection F or number of operating cycles may be increased or the initial operating length L_1 reduced to accomplish the same purpose.

Since it is wasteful to carry through calculations in Step 7 for wire diameters much smaller than d_{min} or greater than d_{max} and both d_{min} and d_{max} are unknown, the designer must use some care in selecting wire sizes above and below d_{opt}. As a rule of thumb, select at least three wire diameters on each side of d_{opt} to cover a diameter range roughly from 0.75 to 1.25 d_{opt}. If this range is too narrow, as will be evidenced when no s_2 calculated is yet larger than s_s, another wire diameter may be selected on either side.

Formal grouping of calculated data, TABLE 1, is generally helpful. It simply condenses all the calculations of Steps 1 to 6 and groups the data required in Step 8. Values of s_2, s_s, P_2, K and perhaps free length, H, are plotted as shown in *Fig.* 5. Free length is plotted when problems in assembly, buckling or tangling may indicate preferable values. It is possible that the designer may wish to plot s_2 for a number of springs with various values of D_o, as in *Fig.* 3, to appraise better the choices at different outside diameters.

Application of the analytical method to a typical problem in compression spring design is detailed in the following discussion.

Problem Example: Design a compression spring to meet the following initial physical and operating specifications. Material is hard-drawn spring steel; $G = 11.5 \times 10^6$ psi. Number of operating cycles is 10,000. $P_1 = 15$ pounds, $L_1 = 4$ inches, $D_o = 1.25$ inches, and $F = 1.50$ inches. Ends are closed and ground; $C = 1.5$.

STEP 1: From Equation 1:

$$d_{opt} = \left[\frac{12(15)(1.05)^3(2.12)}{11.5(10)^6(1.5)} \right]^{1/5} = 0.1206\text{-inch}$$

where a wire-diameter allowance of 0.20-inch is subtracted from D_o to attain $D_m = 1.05$ inches (temporary, for use in calculating d_{opt} only) and $h_{nom} = 0.85\ (4-1.5) = 2.12$ inches.

STEP 2: From Equation 2:

$$N = \frac{2.12}{0.1206} - 1.5 = 16.1 \text{ coils}$$

Although d_{opt} is not a standard wire size, Steps 2 to 6 are completed to obtain the minimum point on the s_2 curve as well as values of K, P_2 and s_s.

STEP 3: From Equation 3:

$$K = \frac{11.5(10)^6\ (0.1206)^4}{8(1.1294)^3\ (16.1)} = 13.1 \text{ lb per inch}$$

STEP 4: From Equation 4:

$$P_2 = 15 + 13.1\ (1.5) = 34.6 \text{ lb}$$

STEP 5: From Equation 5:

$$s_{2\ min} = \frac{8(34.6)\ (1.155)\ (1.1294)}{(3.14)\ (0.1206)^3} = 65{,}700 \text{ psi}$$

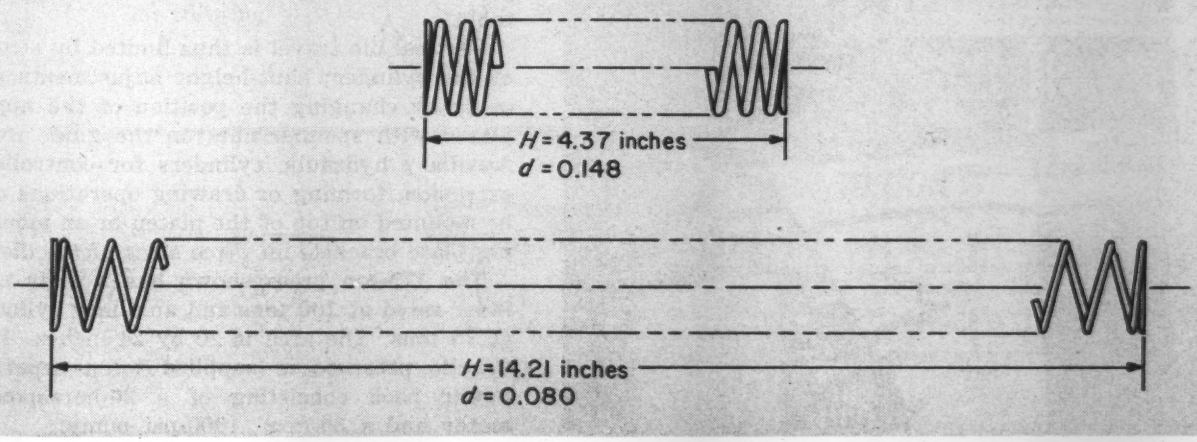
STEP 6: From Equation 6:

$$s_s = \frac{110{,}000}{1.30} = 84{,}600 \text{ psi}$$

where $A = 1.30$ for hard-drawn spring steel operating at 10,000 cycles and within a stress range $(34.6-15)/34.6 = 0.566$. An s_s of 84,600 psi seems a reasonable amount above $s_{2min} = 65{,}700$ psi so that the specifications in Step 1 corresponding to $d_{opt} = 0.1206$ inch are acceptable.

STEP 7: Following the suggested rule of thumb, the designer may select standard wire sizes of 0.1205, 0.1055, 0.0937, 0.0915 and 0.080-inch below $d_{opt} = 0.1206$-inch and 0.135, 0.1483 and 0.156-inch above d_{opt} and proceed with the calculations in TABLE 1 for each. The value $s_{2min} = 85{,}100$ psi at

Fig. 6—Comparison of two spring designs based on d_{min} and d_{max} in *Fig.* 5



the largest wire size of 0.156-inch is well above s_s = 73,300 psi. However, because s_s and s_{2min} are almost equal at d = 0.080-inch, another set of calculations was made at d = 0.072-inch.

STEP 8: The tabular data in TABLE 1 for s_2, s_s, P_2 and K are plotted in *Fig.* 5.

STEP 9: In this step, there are three basic objectives with which the designer reviews the graph in *Fig.* 5: (1) Minimum or low gradient, (2) minimum or low stress, and (3) values of gradient K or final load P which most nearly satisfy application requirements. Minimum gradient is evidently obtained at d_{min} which is equal to 0.080-inch in the example. On the other hand, any gradient below a certain magnitude may be satisfactory; below 5 pounds per inch, for example, in this problem. In such a case the designer would select a wire diameter in the acceptable gradient range which offers the most appropriate final load, P_2.

Minimum stress clearly is obtained at d_{opt}. In this example 0.1205-inch is the nearest standard wire diameter. However, P_2 and K are then fixed; P_2 = 34.6 pounds and K = 13.1 pounds per inch. Since it is evident that s_2 changes comparatively little in the regions of d_{opt} while P_2 and K change rapidly, there is a wide choice in P_2 and K with very little increase in s_2. Here, s_2 changes only 10.6 per cent while P_2 varies from 20.1 to 51.4 pounds and K from 3.4 to 24.3 pounds per inch.

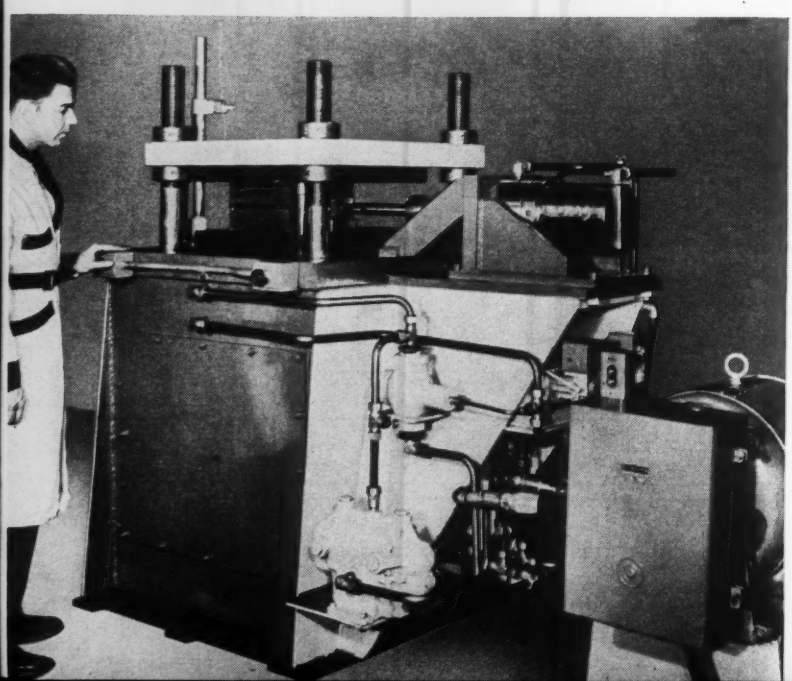
The flexibility afforded by the analytical method is illustrated in *Fig.* 6 by the great difference in size of two compression springs, drawn to scale, which both fulfill the given initial physical and operating specifications. These designs employ d_{min} and d_{max} from *Fig.* 5.

It is evident in *Fig.* 5 that the designer can see at once all possible values of P_2 and K and can select the wire diameter corresponding to the final load or gradient closest to application requirements. Thus, although the magnitude of P_2 and K may not be critical enough to specify initially, there frequently is a maximum or minimum value, or range, which would result in most satisfactory performance. Another consideration in choosing wire diameter is the possibility of manufacturing difficulties, which would increase spring cost, or tangling problems with springs having indexes which are comparatively low or high. It is recommended that the wire diameter selected provide a spring index between 6 and 10. In this example, all wire diameters below 0.114-inch would result in springs with indexes greater than 10.

CONTEMPORARY DESIGN

Inverted Vertical Press

HYDRAULIC control cylinders in a new line of vertical presses are located in the base of the machine, a feature that reduces overall height, removes shut-height limitations, lowers the center of gravity, and provides areas at the top and sides for mounting auxiliary hydraulic cylinders. Manufactured by Walter P. Hill Inc., the presses have large bed areas, and die capacity can be increased by providing long guide rods.



The hydraulic cylinder, operating on 5000 psi pressure supplied by a 5 to 1 hydraulic booster, is flange-mounted on the bottom of the die table. Piston rod is in a vertical position, extending downward toward the welded-steel base of the press, and actuates the upper platen through the four widely spaced rods guided in individual bushings in the press table.

Vertical die travel is thus limited by stroke of the cylinder; shut-height adjustments are made by changing the position of the upper platen with spanner nuts on the guide rods. Auxiliary hydraulic cylinders for controlling extrusion, forming or drawing operations can be mounted on top of the platen or on mounting plate brackets on three sides of the die.

The 175-ton press shown has a main cylinder rated at 100 tons and auxiliary cylinder at 75 tons. Die area is 20 by 24 inches. Hydraulic pressure is supplied by a separate power pack consisting of a 20-horsepower motor and a 30-gpm, 1000-psi pump.

PRODUCTION AND DESIGN

Designing Small Die Castings

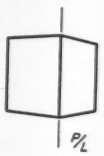
SMALL die castings offer numerous design advantages in cost reduction through simplification or elimination of machining and assembly operations. Typical mechanical parts produced include pinions with shafts, valve parts, adjusting latches, special washers, small face gear assemblies, etc. Cast in Zamal 3 or 5 alloys, maximum weight of these small parts generally runs to ½-ounce and length to 1¾ inches with smallness virtually unlimited.

To utilize the advantages possible by die casting such intricate parts, quantity is important. Automatically produced, die castings in this category require runs from 100,000 pieces up into the millions. Also important is design. To assure suitable design features on small parts basic recommendations shown in the accompanying sketches should be given careful consideration.

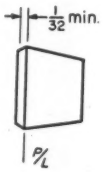
Data in this article, courtesy Gries Reproducer Corp.

PARTING LINES

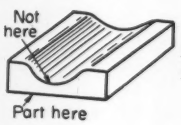
If appearance is important, add rib or bead if possible. This hides the parting line and looks better



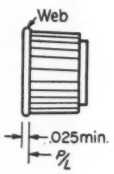
Allow ample taper on all surfaces leading away from the parting line. Minimum is 0.004-inch per inch—more if possible



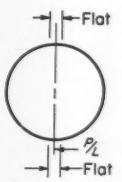
Keep parting lines away from edges if a trimming breakout is undesirable. On the other hand, tooling is generally less expensive if parting line is on an edge



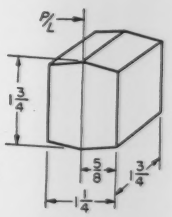
Avoid irregular parting lines. Try to keep all in one plane



Add web when casting knurls, gears or serrations. This simplifies the trimming



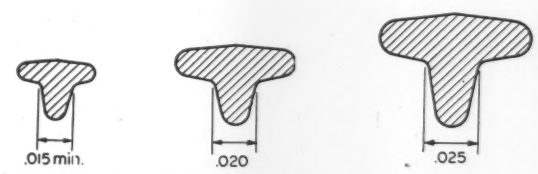
When parting on a diameter, flats as illustrated afford closer diametral tolerances



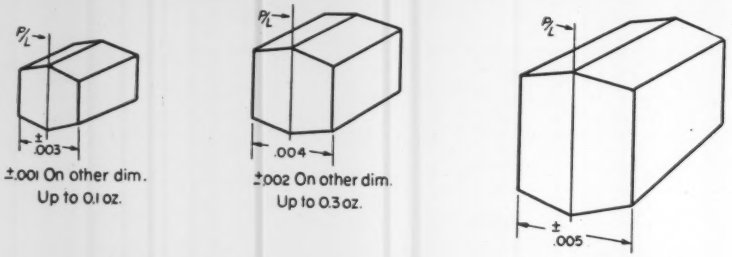
SIZES OF CASTINGS

Make casting as small as design permits. Castings which approach the largest size limits shown must be lightened in some way so as to remain within weight limits

SECTION THICKNESS



Minimum sections are indicated. Short, stubby castings may use thinner sections, while long, slender castings may require thicker sections. Keep sections as uniform as design permits and avoid abrupt section changes. Minimum wall thickness possible to cast is 0.006-inch

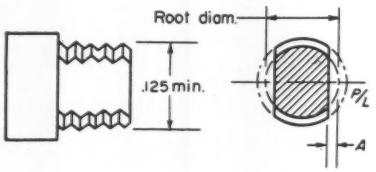


TOLERANCES

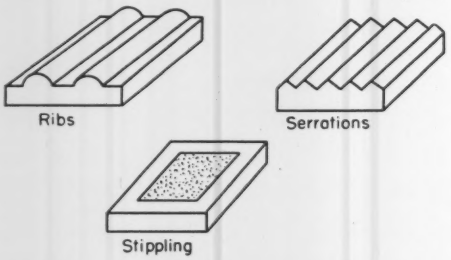
General tolerances are shown. These may be modified by the type of casting. Tolerances can also be closer, but cost will be higher

THREADS

External threads can be cast within limits shown. The flats as indicated are preferred but in some cases full threads can be cast, depending on diameter and pitch. Maximum pitch is 32 per inch

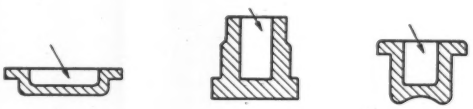


Root diam	A
0.100	0.003
0.250	0.005
0.500	0.008
0.750	0.010
1.000	0.015
1. Plus	0.015



UNBROKEN SURFACES

Avoid large plain surfaces. Break where possible with a design feature such as ribs, serrations or stripping

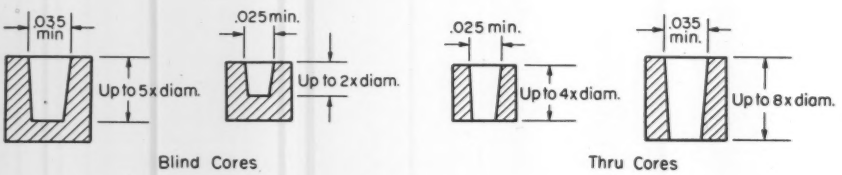


METAL SAVERS

Use metal savers to reduce weights of castings. This is important even on very small castings where the individual weight is so little that it may seem unnecessary. With large quantities the savings are almost always worthwhile

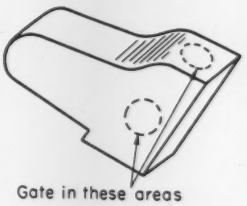
CORING

Use as much draft as possible. A good taper is 0.015-inch per inch on diameter. Minimum taper on all cores is 0.005-inch per inch on diameter. Add a reaming operation where straight hole is required

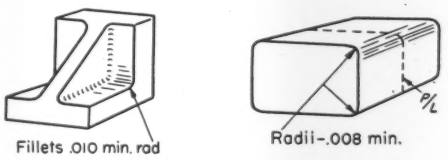


AND DESIGN

GATES AND RUNNERS



Indicate the desired location of gates or runners. If possible, give more than one choice

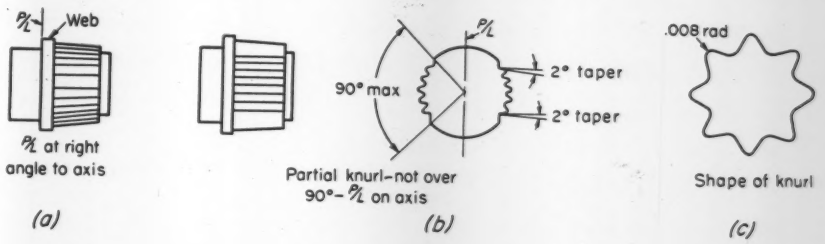


FILLETS AND RADII

Use fillets for strength and generally better castings. Use radii on all corners at right angles to the parting line. This aids in making the casting dies

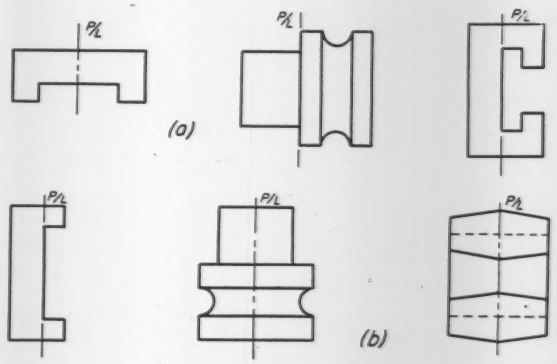
KNURLS AND SERRATIONS

Design knurls or serrations as shown at *a* and *b*. Use shape of knurl as shown at *c*. Use as few serrations as possible. This aids in better appearance of knurl



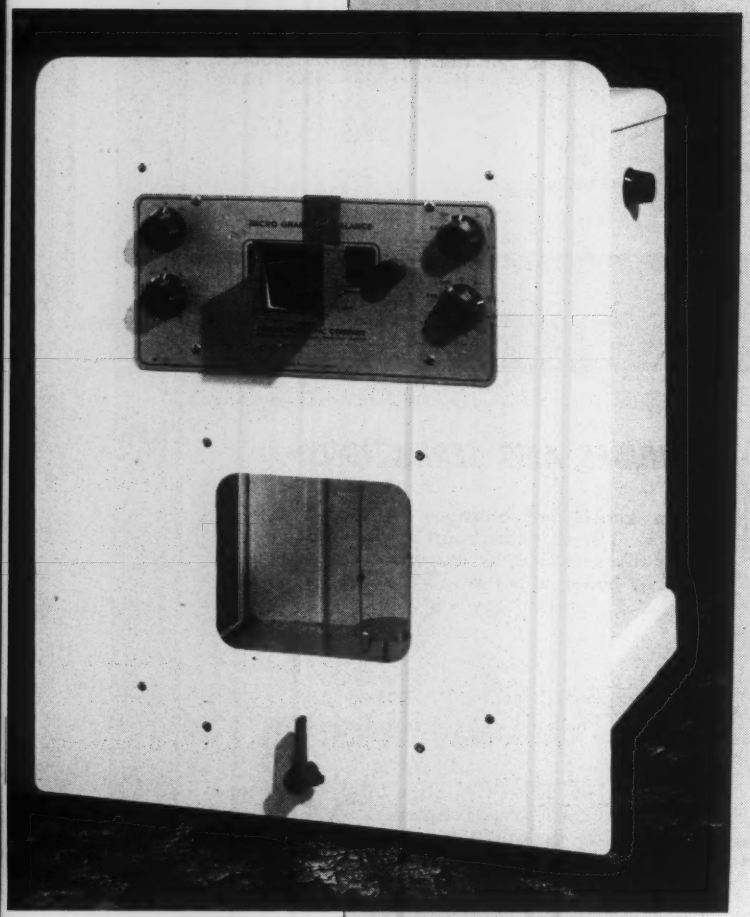
LETTERING

Lettering should either be raised as at *a* or in a depressed panel as at *b*. Depressed lettering can be produced but costs considerably more



UNDERCUTS

Avoid sections such as shown at *a*. These cannot be ejected without complicated coring. Redesign or change the parting line as shown at *b*



Balance Operates by Removing Weights with Cam System

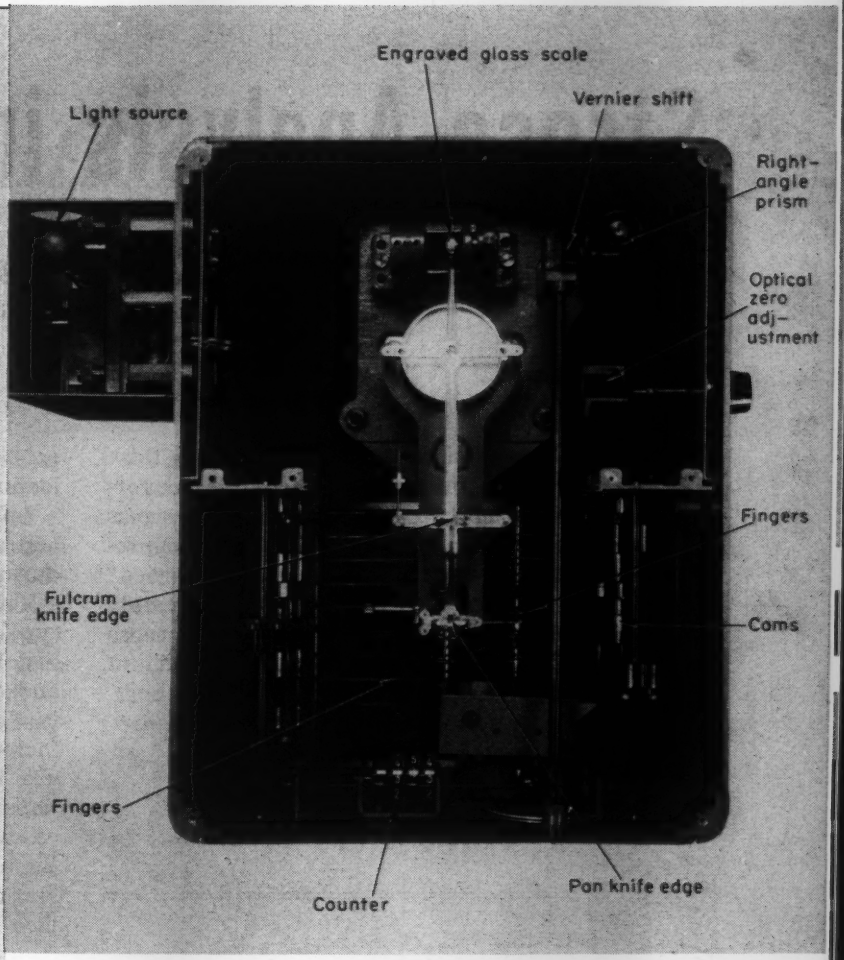
WEIGHTS are removed by a system of cam-actuated fingers in the new Micro Gram-atic balance of Fisher Scientific Co. to permit dialing and automatic totalling of weight rather than actual physical handling of weights and laborious calculation of final results. Based on a principle developed several years ago for larger balances, the Micro Gram-atic has several design improvements over earlier types.

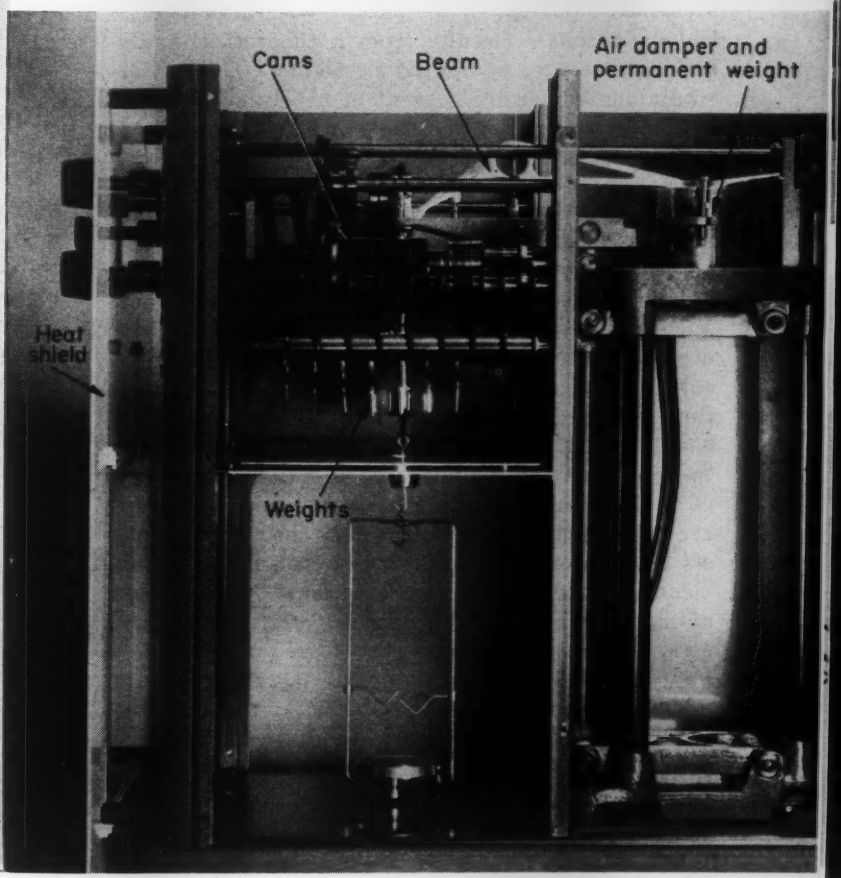
The balance reads from 20 grams down to 0.000001-gram with accuracy of ±0.002-milligram. Two decimal places (0.01-gram) are read directly from a counter; two more from an optical scale projected on a ground-glass screen just to the right of the counter; and the fifth and sixth places by means of a circular vernier disk. Upper left knob removes and replaces a 10-gram weight; lower left weighs in multiples of 1 gram; upper right, 0.1-gram; and lower right, 0.01-gram. Knob at center adjusts the vernier disk.

Mechanical weighing system involves a machined aluminum beam with a permanent fixed weight behind the fulcrum and an air damping system to bring the beam to rest. Removable weights hung on notched bars in front of the fulcrum exactly balance the fixed weight; when a sample is placed on the balance pan, weights are removed to compensate for the additional sample weight. Cam and knobs are geared to the counter.

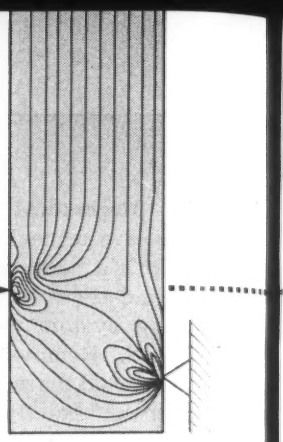
To remove weights, fingers which are permanently hooked under the weight hangers are lifted by cams in combinations depending upon the total weight. Two knobs on the left side control nine weights, four 0.5-gram, two 1-gram, two 2.5-gram and one 10-gram weights. Upper left control knob raises or lowers the 10-gram weight; lower left knob controls multiples of the other nine to produce readings up to 9 grams. These nine larger weights are balanced about the 10-gram weight at the center of the hanger to provide fore and aft stability, and are removed in pairs. On the right side are two sets of weights; two 0.1, one 0.2 and one 0.5-gram controlled by the upper right knob; and two 0.01, one 0.02 and one 0.05-gram controlled by the lower right knob.

After approximate balancing with weights, the beam is released and deflects due to a slight surplus of sample load. Amount of deflection is determined by the method of mounting the fixed weight. Center of gravity of the fixed weight is located below the beam axis; consequently, with deflection, effective length of the fixed weight moment arm is increased. Deflection, essentially linear because the beam is under constant load, is indicated by projection of an engraved glass scale at the back of the beam on the ground-glass screen at the front of the balance. A circular glass vernier prism and a zero-adjustment prism are located in the light beam.





Stress Analysis in Design



By J. B. Hartman and R. E. Benner
Department of Mechanical Engineering
Lehigh University
Bethlehem, Pa.

A BASIC question facing the designer is this: Is the stress predicted by a particular formula sufficiently close to the actual stress state within a member to be a useful guide for predicting the performance of that member in service? Because the answer to this question rests mainly with the designer, he should be familiar with those factors that limit the reliability or applicability of theoretical methods.

General Assumptions

Assumptions made to facilitate a theoretical analysis are not always compatible with actual physical conditions. Results from a theoretical analysis are therefore of limited reliability. General assumptions which are present in nearly every application of strength of materials or elasticity methods will be discussed first.

Loading: One of the greatest limitations of theoretical stress analysis arises through the difficulty of accurately predicting the magnitude and distribution of loads to which a member will be subjected in service. Regardless of how perfect theoretical formulas are, they cannot give reliable results if actual loading differs fundamentally from that assumed for the analysis. The laws of mechanics must be utilized with the utmost caution to determine the magnitudes, directions and points of application of loads. Even then, very often there are loading conditions which defy theoretical analysis because of the complexity or because of insufficient knowledge of service conditions. Experimental methods, such as the use of electric-resistance strain-gage load cells, may be used to provide a valuable backlog of loading data for future designs.

Until recently, most theoretical work in stress analysis had been devoted to cases of statically applied loads. With the advent of high-speed machinery, dynamic loading became a crucial problem in machine design. Theoretical analysis of dynamically loaded systems is often inadequate. Impact and repeated loading are examples of dynamic loading which impose difficulties.

Impact loads are applied to the surface of a body and are characterized by the brief duration of time during which this application takes place. The effect an impact load produces depends upon the type of load pulse, the abruptness of application, and the relation between the time of disturbance and the natural period of the system, as indicated in *Fig.* 3 (Part 1, March issue). A dynamic load factor may be determined if these characteristics are known and although calculation of the peak impact load is usually difficult, it may in some cases be evaluated satisfactorily by the principle of impulse and momentum. Use of an equivalent static load based upon a single dynamic load factor is restricted to systems which exhibit response characteristics comparable to those of a single degree of freedom. Once equivalent static loads have been determined, corresponding stresses can be calculated with equations derived for static systems.

If the duration of load application is extremely short compared to the time required for elastic waves to reverberate throughout a body, the impact problem is more complex. Waves initiated at the point of impact propagate throughout the member as shown in *Fig.* 10. New disturbances radiate in all directions whenever the initial waves reach a boundary of the body. The stress at any given point within the member will be the resultant of the various stress waves to which that point is subjected. Analysis of these waves is possible; however, the analysis is relatively complex so that only simple cases have been treated.[1, 2] In general, the impact problems which constantly face the designer do not yield readily to theoretical analysis.

The terms *repeated load* or *fluctuating load* are sometimes used to describe dynamic loads which vary periodically with time, *Fig.* 11, whose frequency of variation with time is small in comparison with the fundamental frequency, and for which there is no abrupt change throughout any cycle. Under these circumstances, even though the member is subjected to forced vibration, the accelerations have a negligible effect upon stress. Consequently, static formulas are sufficiently exact for repeated load problems. Natural frequencies should

[1, 2] References are tabulated at end of article.

Part 2—Limitations of Theoretical Methods

be calculated whenever possible to insure the validity of static formulas.

One major limitation in the adequate analysis of repeated load problems by theoretical methods lies in the lack of suitable criteria of failure. The commonly used fatigue tests do not supply the information required to design satisfactorily for complex states of stress, for example. Other problems, such as the effects of random loads and residual stress on fatigue life, make design for fluctuating loads less exact than desirable.[3]

Stress distributions in regions of a body near the points where surface forces are applied is radically influenced by the presence of these forces. A formula developed without consideration of this effect would not be reliable if used to analyze stress in the vicinity of a loaded surface, *Fig.* 12. This limitation applies to the majority of formulas, particularly those developed in strength of materials. Such formulas may be used however when analyz-

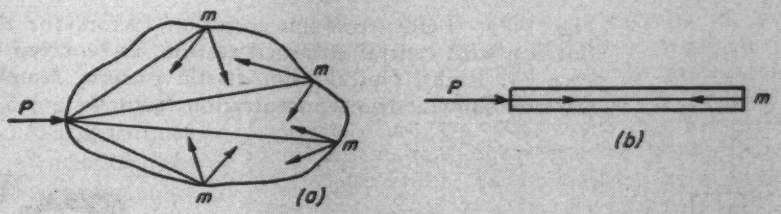


Fig. 10—Propagation of elastic waves in (*a*) a two-dimensional body, and (*b*), a one-dimensional body. Waves initiated by application of impact load *P* create new disturbances, at points *m* for example, which continue to reverberate throughout the body

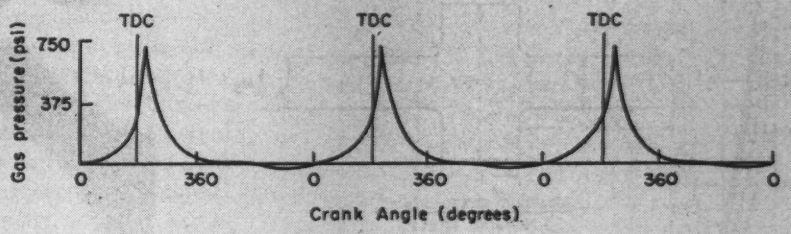
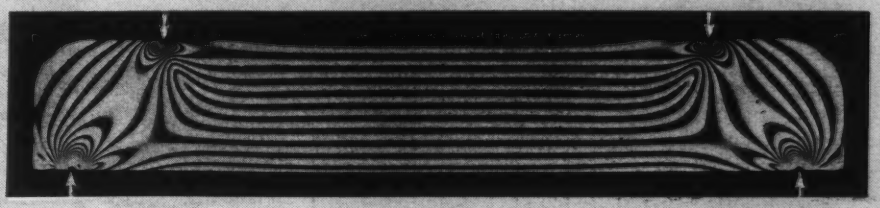


Fig. 11—Variation of gas pressure within the cylinder of an internal combustion engine—an example of repeated load

Fig. 12—Stress distribution in the vicinity of surface forces, as shown photoelastically by Frocht (Reference 4). The irregularity of stress distribution in regions of the body near the points of application of load is evident. The simple flexure formula *My/I* would provide reasonable results only for the central portion of the beam where the pattern is regular



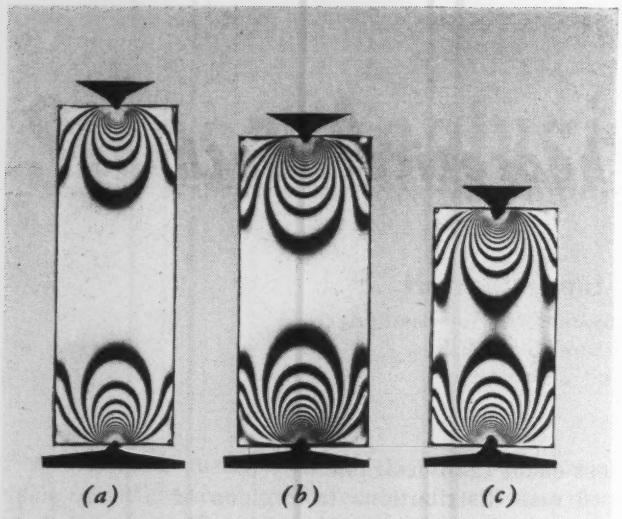
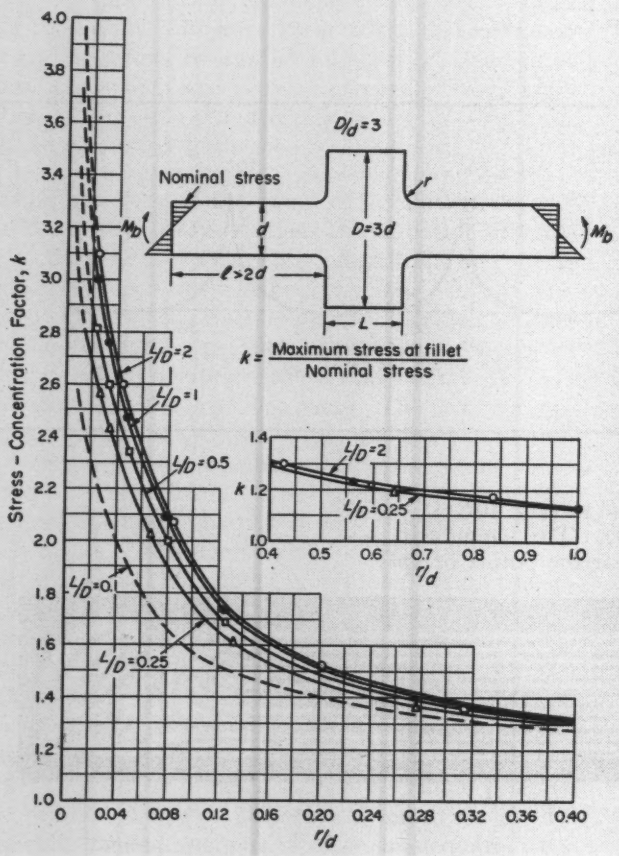


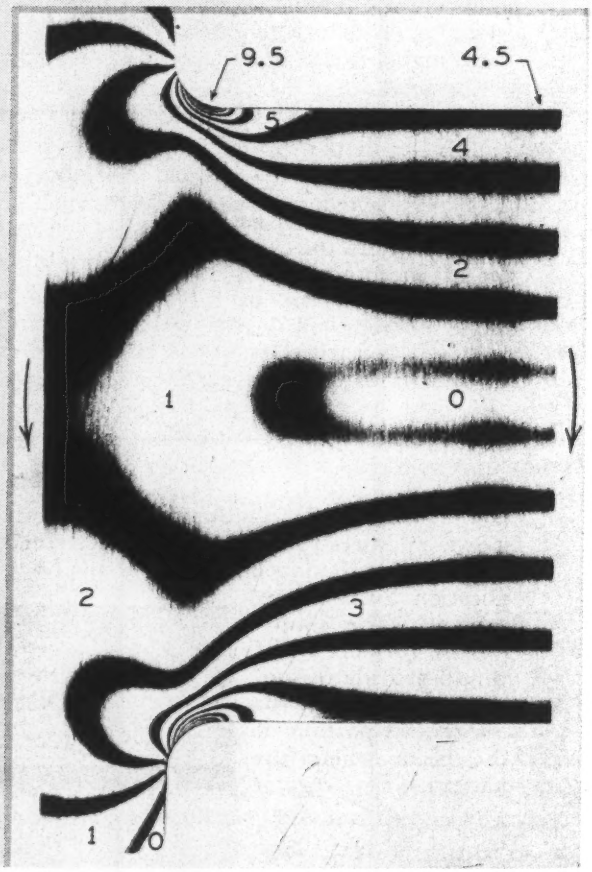
Fig. 13—Influence of surface forces, as shown photoelastically by Frocht (Reference 5). The local influence of the concentrated loads in *a* does not extend to the central portion of the member and the formula *P/A* would apply to this section. Such is not the case for a shorter member such as that shown in *c* where there are no "remote" regions and *P/A* does not apply

ing sections of a body remote from loaded boundaries.

Failures sometimes occur in regions of load application. Also, there are cases in which the volume of a body is small in comparison with the extent of loaded surface so that the effects of applied loads are manifest throughout the entire body; that is, there are no remote regions. *Fig.* 13 shows an example of this situation. For these reasons it is desirable to have a method of analyzing those portions of a body in the vicinity of surface forces. Strength of materials is impotent for cases of this type; therefore, elasticity or experimental methods must be utilized. In strength of materials, stress distribution must be determined by predicting strain distribution. In complex situations, it is impossible to predict strain distribution; hence, the method fails. Elasticity is unhampered by this limitation. Only a small differential element is analyzed when the equations of equilibrium and compatibility are set up so that if a solution satisfying the boundary conditions can be found, that solution will be a correct one even though the region considered is near points of load application. Mathematical difficulties pro-

Fig. 14 — Left, stress-concentration factors for the bending case of fillets in a flat bar with central enlarged section, as reported by Hartman and Leven (Reference 7). Right, typical photoelastic pattern. Numbers refer to fringe order. For the case shown, stress-concentration factor $k = 9.5/4.5 = 2.11$ for the upper fillet





vide a limitation to the use of elasticity in solving problems of this type although practical problems have been investigated. Photoelasticity is an experimental method which has proven especially useful in analyzing problems of this type.

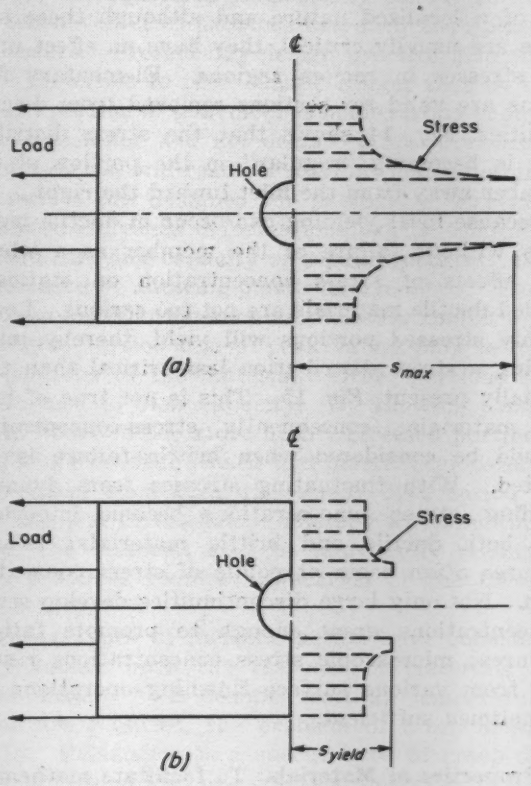
The principle of Saint-Venant states that forces acting upon a small part of the surface of a body may be replaced by a statically equivalent system of forces acting upon the same portion of surface without disturbing the stresses in regions of the body which are removed from the load by distances large in comparison with the linear dimensions of the loaded surface. In place of the concentrated loads pictured in *Fig. 13a,* for example, uniformly distributed loads (of suitable magnitude) could be applied across each end of the member without altering the stresses in the central (remote) portion of the member. The stress field would change only in the regions near each end.

Equivalent systems are often used in mechanics to replace complex loads and there is complete justification for this procedure. Very often points of application of the equivalent loads are different from the original system and while this makes no difference in mechanics it makes considerable difference in the distribution of stress in regions near loaded boundaries. The state of stress within a body is determined not only by the magnitude of external loads but also by their directions and points of application. Saint-Venant's principle is of great aid when analyzing problems using the elementary formulas of strength of materials. Complex loads can sometimes be replaced by a statically equivalent system of axial forces, torques, and bending moments and the stresses induced by each may be calculated by elementary formulas. By superposition of effects, the resultant stress system may then be determined. It is important to remember that such a procedure is valid only when analyzing sections remote from loaded boundaries. Saint-Venant's principle is also of considerable importance in elasticity. Often a solution to the elasticity equations can be found which fails to satisfy the boundary conditions supplied by the surface forces. If the stress distribution at the loaded boundary is statically equivalent to the applied load and is on the same portion of surface as the actual load, that solution may be regarded as valid in remote regions.

Small Strains: The development of theoretical formulas in strength of materials and elasticity is based upon the assumption that all strains are small in comparison to unity. This assumption is used to justify neglecting higher order terms involving strains in the theoretical developments. It is this assumption which also makes valid the principle of superposition of effects. When the theory of finite deformations of an elastic body is developed, the principle of superposition is no longer valid.[6] This complicates matters considerably. Technical metals used in design are seldom stressed beyond their yield points and for this range only small strains result; therefore, the assumption of small strains imposes no serious limitation on theoretical stress analysis for the common applications.

Discontinuity of Section: It has been mentioned that the necessity of predicting strain distribution imposes a serious limitation on strength of materials. Since prediction of strain distribution over cross sections in the vicinity of abrupt changes in section is impossible, the elementary approach is impotent for these cases. Holes, notches, shoulders and the like represent discontinuities of cross section for which strength of materials is useless. This state of affairs led to the concept of stress-concentration factors. These factors are correction factors applied to the elementary formulas (developed upon the assumption of continuity of section) to allow their use in regions of discontinuity. The ratio of the stress actually present at the discontinuity to the stress given by the pertinent formula

Fig. 15—Stress concentration in ductile and brittle materials. Sketch *a* shows the distribution of stress in a statically loaded plate containing a circular hole. The concentration of stress near the hole is evident. If the material is brittle and s_{max} exceeds its tensile strength, a crack is likely to form which could lead to fracture. In a ductile material, such as at *b*, if s_{max} exceeds the yield point, localized plastic flow can occur which may be sufficient to relieve the highly stressed region but not cause failure of the member as a whole



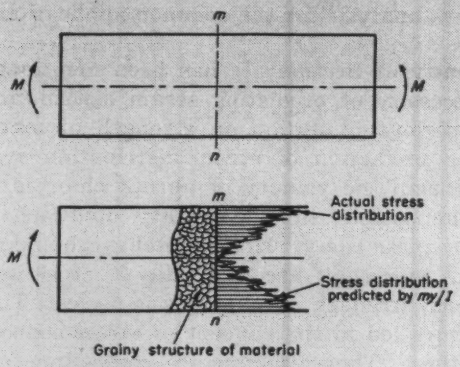


Fig. 16 — Effects of nonhomogeneity on a beam subjected to pure bending. Because of the nonhomogeneous or grainy structure of the material, the actual stress distribution differs from that predicted by the flexure formula: $s = My/I$

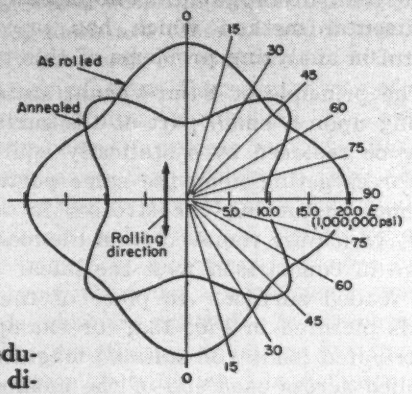


Fig. 17—Variation of modulus of elasticity E with direction in copper as shown by Weerts (Reference 10)

for a continuous section is defined as the stress-concentration factor. Its magnitude depends upon a relationship among dimensional parameters of the specific member, *Fig.* 14.

The evaluation of stress-concentration factors requires the use of experimental methods or the use of the theory of elasticity. Photoelasticity has proven to be the most powerful single method of investigation although elasticity has also been used. Reference to standard works on the theory of elasticity will disclose numerous practical investigations. Theoretical and experimental results compare favorably although the former tends to give higher values.

As true in the case of surface force effects, stress concentrations due to geometrical discontinuities are of a localized nature and although these sections are usually critical, they have no effect upon the stresses in remote regions. Elementary formulas are valid for sections removed from discontinuities. *Fig.* 14 shows that the stress distribution is becoming "regular" in the portion of the member away from the fillet toward the right.

Because local yielding can occur in ductile materials without failure of the member as a whole, the effects of stress concentration on statically loaded ductile materials are not too serious. Local, highly stressed portions will yield, thereby introducing a stress distribution less critical than that initially present, *Fig.* 15. This is not true of brittle materials; consequently stress-concentration should be considered when brittle failure is expected. With fluctuating stresses from dynamic loading, stress concentrations become important for both ductile and brittle materials; fatigue failures often begin at points of stress concentration. Not only large discontinuities develop stress concentrations great enough to promote fatigue failures; microscopic stress concentrations resulting from various surface finishing operations are sometimes sufficient.

Properties of Materials: To facilitate mathematical developments in the theory of elasticity and strength of materials, a material is assumed to possess certain ideal properties. Actual materials may exhibit properties which differ significantly from the ideal; if so, theoretical formulas are rendered less reliable.

CONTINUITY: A continuous material is one which is free of discontinuities such as cracks, inclusions, or blow holes. Theoretical formulas are developed upon the assumption that every material is continuous. When applied to a discontinuous material, they cannot be expected to give reliable results. Failures do occur because of such imperfections. Elasticity can be used to investigate stresses resulting from flaws; however, the difficulty of analysis and unpredictableness of such imperfections make a theoretical approach impractical. The designer has little alternative but to assume that sound materials are to be used in the construction of his design.

HOMOGENEITY: Elastic properties of the ideal material are assumed to be identical for all portions of the material, no matter how finely it may be divided. If the condition of homogeneity were not satisfied, various elastic properties would not be constant but would vary in magnitude from point to point within the material. Due to the grainy constitution of many important engineering metals, they cannot be considered homogeneous, *Fig.* 16, but because the grains are oriented at random and are very small in comparison to the linear dimensions of the smallest machine part, lack of homogeneity due to grainy constitution is of little practical importance. This is not true in certain other instances; wood is a fibrous material and definitely not homogeneous.

There exist two other types of inhomogeneity.[8] One relates to composition, the other to structure. Such processes as carburizing, decarburizing, nitriding, or calorizing change the composition of surface layers of treated metals, thus causing surface inhomogeneity. The concentration of impurities near the inner core of an ingot persist even after rolling, causing inhomogeneity in composition. Lack of homogeneity resulting from structure dif-

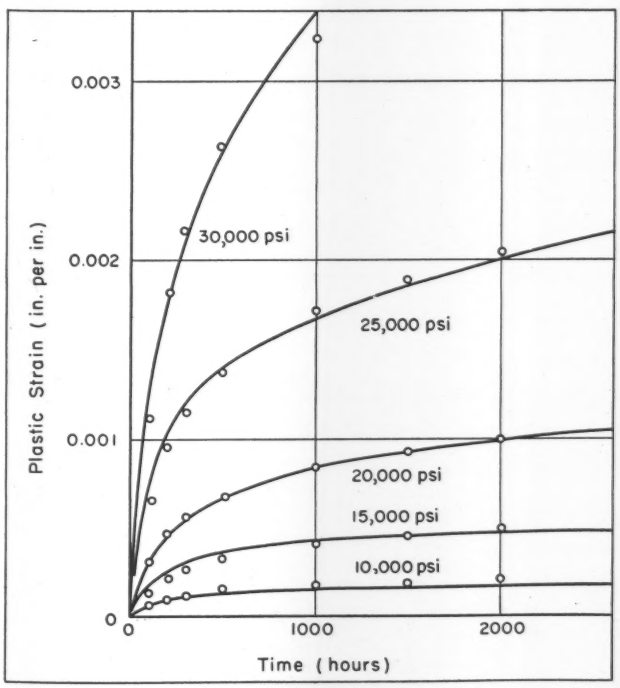
ferences often arises in heat-treatment processes. For example, when heavy steel castings are quenched, the outer layers may be martensitic and very hard while the core becomes pearlitic and soft.

Experimental investigation has shown that in the case of steels, inhomogeneity resulting from composition or structure has little influence on elastic properties. From this it may be inferred that for many important engineering metals, inhomogeneity imposes no serious limitation upon theoretical stress analysis.

ISOTROPY: An isotropic material is one for which elastic properties remain the same regardless of the direction in which they are determined. The assumption of an isotropic material greatly simplifies strain analysis in elasticity. It is always assumed in strength of materials. *Anisotropy* denotes the circumstance in which elastic properties vary with direction.

If a body is homogenous, the elastic coefficients relating stress to strain are constants and if in addition the body is isotropic, it may be shown that the required number of elastic coefficients reduces to two. Young's modulus, Poisson's ratio, and the modulus of rigidity are three elastic constants in common usage; for an isotropic body only two of the three are independent. For the most general anisotropic material the relation of stress to strain requires the use of 21 independent coefficients; for simpler cases which include most technical metals, only three independent elastic coefficients are necessary. The theory of elasticity has been applied to cases of anisotropic materials.[9]

Fig. 18—Creep-time curves for 12 per cent chromium steel at 850 F reported by Soderberg (Reference 15). Many metals when subjected to constant stress (below yield point) and elevated temperatures will deform plastically over a long period of time. The early phase of such deformation, creep, is shown. This phenomenon has practical importance in the design of steam and gas turbines, for example



Fibrous materials like wood are anisotropic. Most structural metals are considered to be isotropic because of the chaotic distribution and small size crystals. This assumption although satisfactory in many instances is not valid under other circumstances. Processed metals such as cold-rolled sheet show a decided variation in elastic properties with direction; the modulus of elasticity may vary as much as 30 per cent in rolled sheet iron and 80 per cent in rolled and annealed copper, *Fig.* 17. It is apparent that serious limitations upon the reliability of theoretical computations may result if anisotropy is ignored.

PERFECT ELASTICITY: A material is considered to be perfectly elastic if upon removal of applied loads, all deformations due to those loads immediately disappear. Different types of inelastic behavior may be observed in most engineering materials.[11]

Plasticity is one important type of inelastic behavior which concerns the designer. Depending upon loading conditions, materials normally classified as ductile or brittle may flow plastically. Apparently there is no physical basis for the classifications *ductile* or *brittle;* these terms apply only under restricted conditions. Because the assumption of a single-valued, time-independent relationship between force and deformation is made in the theory of elasticity (i.e., perfect elasticity is assumed), the equations of elasticity cannot be utilized whenever circumstances are such that plastic flow occurs. Present-day design practice generally limits materials to their elastic range; that is, the weakest portion of a member is made strong enough so that yielding will not occur. More economical use of material will result if machine and structural components are designed for plasticity. Provided associated increased deformations can be tolerated, the load-carrying capacity of certain members may be increased by allowing plastic flow to occur. Elastic stress distribution such as those associated with bending or torsion rise to peak values only in limited portions of the material. Other portions are not stressed to their capacity. By allowing plastic flow to occur in the more highly stressed portions, equilibrium between elastic and plastic regions may be obtained such that the stress distribution is more uniform throughout. Thereby the potentialities of the material may be more fully realized. These problems require application of the theory of plasticity.[12, 13]

Other types of inelastic action have considerable influence upon the response of materials to applied load.[11, 14] If designs for high temperature service are required, the problem of creep arises, *Fig.* 18. Relaxation is a special type of creep deformation which also has practical importance, *Fig.* 19. Work hardening and anelasticity are still other

types of inelastic behavior which affect the performance of materials. It soon becomes apparent that inelasticity is the rule rather than the exception and, depending upon the problem at hand, consideration must be given to inelastic response.

HOOKE'S LAW: In addition to the assumption that a single-valued, time-independent relationship exists between stress and strain, both the methods of strength of materials and classical elasticity assume Hooke's law. This law in its most general form states that each component of stress is a linear function of the components of strain. Lack of homogeneity is a primary reason for the fact that real materials do not behave according to Hooke's law within the range of small deformations. The stress-strain relationships for actual materials may be determined experimentally.[14]

It is fortunate that many widely used materials exhibit a linear relationship very closely. Such is the case for steel. There are materials of engineering importance, however, which show considerable deviation from Hooke's law, *Fig.* 20. Formulas based upon Hooke's law will apply only for the range of stress in which the material involved obeys this linear relationship. These formulas are not valid above the proportional limit (if such exists) of any material. Although nonlinear analysis is possible, the mathematical difficulties involved make this approach impractical for the usual design problems. The alternative is to apply "linear" elasticity recognizing that the reliability of results is affected by the closeness with which real materials obey Hooke's law.

Restricted Assumptions

The preceding assumptions and limitations are usually present in all theoretical developments. There are additional assumptions made in strength of materials and elasticity which are peculiar to and apply to specific developments.

To formulate strain distribution necessary in the development of formulas of strength of materials, the deformation of the member is investigated. Commensurate with shape and loading, a member will deform in a unique manner. Assumptions are often made concerning the nature of this deformation which facilitate a formulation of the strain distribution. An example may be provided by considering the development of the flexure formula: $s = Mc/I$. In this development, the assumption is made that plane sections initially perpendicular to the longitudinal axis of the beam remain plane and perpendicular to the axis after bending, *Fig.* 2 (Part 1, March issue). With this assumption it may

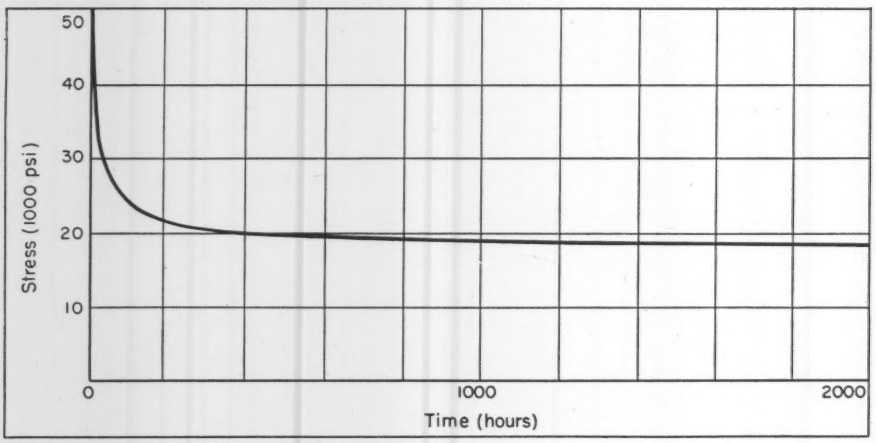
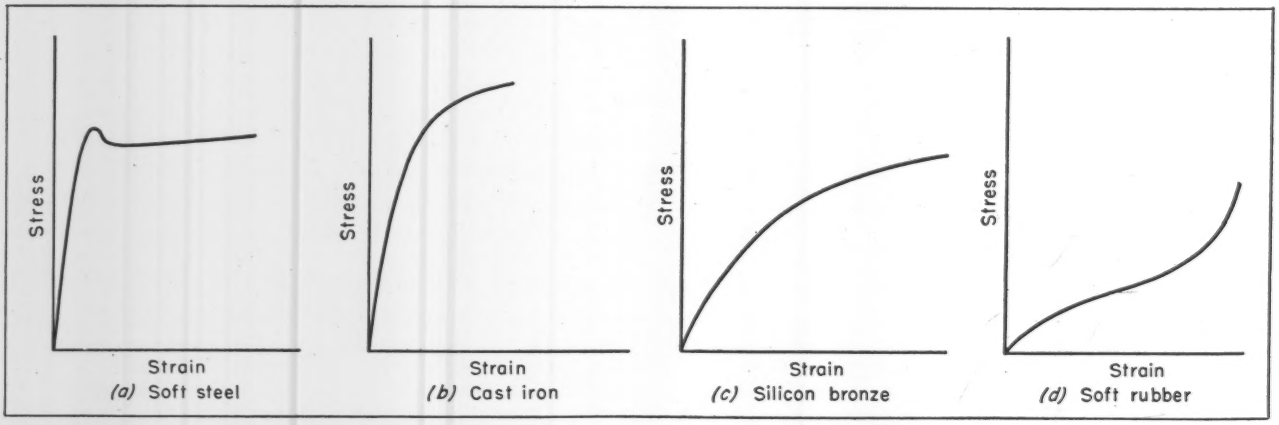


Fig. 19—Left—Relaxation of 12 per cent chromium steel at 850 F shown by Soderberg. Relaxation is a creep phenomenon in which stresses decrease with time in a material subjected to a constant elongation. The initial tension in a bolt, for example, may decrease with time due to relaxation

Fig. 20 — Below — Typical stress-strain curves for several materials



be shown that strain is proportional to distance measured from the neutral surface of the beam. Assumptions of this nature sometimes may be experimentally verified and their use justified upon this experimental basis. Experimental evidence should be investigated whenever possible to insure satisfactory agreement between the assumed and actual elastic behavior.

Restricted assumptions arise in the theory of elasticity when solutions are obtained by use of the semi-inverse method. It may be recalled that assumptions are made regarding the components of stress, strain or displacement. These assumptions impose no additional limitations on elasticity because, once a solution of the elasticity equations is found, it is unique.

Residual Stress: Theoretical formulas developed by the methods discussed above are utilized to predict stresses arising from the application of external loads. There are factors not considered by these formulas which affect the strength of machine and structural components. Among these factors, residual stress is of primary importance.

Stress existent in bodies free from external load are called initial or residual stresses. Residual stress may result from misfits, dislocations, changes in specific volume or distortions.[8]

Whenever parts of an assembly or structure are forced together and are prevented from assuming their original dimensions, residual stresses are introduced because of the misfits. Misfits may be intentional as in the case of shrink or press fits. If a disk is shrunk on a shaft, there will be residual compressive stresses in the shaft and residual tensile and compressive stresses in the disk. It is possible that failure could result from these residual stresses alone. Occasionally residual stresses are introduced unintentionally when parts of improper size are forced together.

Dislocation refers to the displacement of one portion of a solid body relative to another. If a straight thin rod were bent to form a hoop and the ends fastened together, the rod would contain residual stress even though all external loads were removed.

Whenever a portion of a body undergoes change in volume which is not uniform throughout the entire body, residual stresses will result. Nonuniform volume changes may be caused by several different mechanisms. Temperature gradients, such as those present in the walls of boiler tubes, cause unequal expansions throughout the walls which result in residual stresses. Temperature gradients and nonuniform change of phase often occur in heat treatment processes and cause volume disparities throughout the material, *Fig.* 21. Very often cracks in the treated material will result from the residual stresses thus induced. Addition or removal of substance, such as carbon in case-hardening or decarburization, causes volume changes which are nonuniform because only surface layers are influenced.

Certain mechanical processes plastically deform only portions of a body; residual stresses result because of the nonuniform nature of these deformations. In cold rolling for example, the deformations are not uniform throughout the depth of the sheet. "Plastic prestressing" is sometimes used to increase the load carrying capacity of pressure vessels.[17] The vessel is subjected to an internal pressure which causes plastic action of the more highly stressed inner portions of the vessel wall. Upon release of pressure, a residual compressive stress system remains within the inner portions of the wall, as shown in *Fig.* 22. These residual compressive stresses have a beneficial effect upon stress distribution when service pressures are subsequently introduced. Residual stresses are sometimes present in surface layers because of plastic distortion resulting from certain finishing operations. Grinding cracks are failures resulting from plastic deformations during the grinding operations.

Formulas developed to predict stresses resulting from external loads are based upon the assumption that no residual stresses are present. It is apparent that these formulas will give incorrect results if residual stresses are present but are not considered. Because residual stresses often appear in members and may be of sufficient magnitude to influence

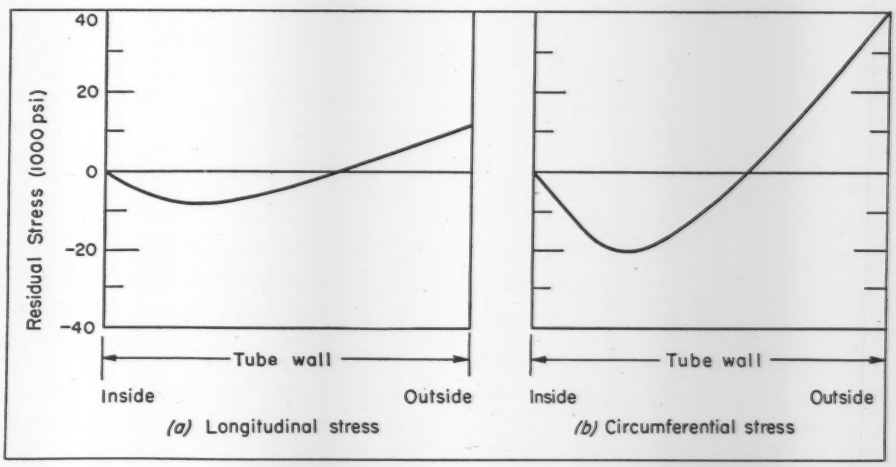


Fig. 21—Residual stresses in normalized chromium-molybdenum steel (SAE X4130) tubing, 3-inch outside diameter, 0.250-inch wall thickness, reported by Sachs and Campbell (Reference 16)

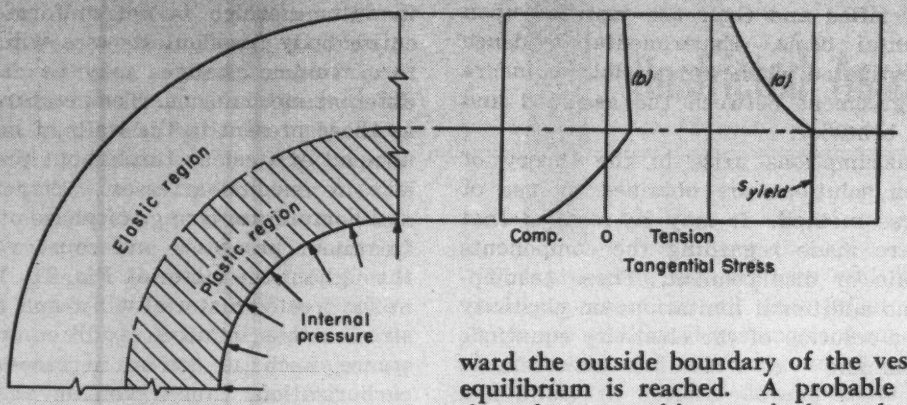


Fig. 22—Plastic prestressing of a pressure vessel. As internal pressure is applied, the more highly stressed inner fibers yield and pass load onto an adjacent layer of fibers. In this manner, the plastic region expands toward the outside boundary of the vessel until equilibrium is reached. A probable distribution of stress at this stage is shown by curve *a*. If the internal pressure is relased, a residual stress system similar to the one shown by curve *b* will remain. Reapplication of the original pressure will produce the original stress distribution, *a*. However, this time no plastic flow will occur

tremendously the stress state, it would be desirable to have a method of predicting their magnitude and distribution. Further, a method of combining residual stresses with stresses induced by external loads is necessary so that the resultant stress state can be predicted.

Combining residual and load stress systems is a relatively simple matter in the case of statically applied, external loads. Each system is independent of the other so that each may be investigated separately. The resultant stress system can be obtained by superposition. Stresses resulting from external loads may be calculated by the usual theoretical formulas but the determination of residual stresses offers a more complicated problem. The investigation of residual stress by theoretical methods is very complex and has largely given way to experimental methods. However, experimental methods also are powerless in certain cases. The interaction of residual and external load stress systems for the case of dynamically applied loads is not well understood. There is evidence that residual stress systems "fade" under the action of externally applied fluctuating loads, but the influence of residual stresses upon the fatigue life of a material has not been satisfactorily established.[18]

Because residual stresses have been the cause of many failures in the past, they have gained a poor reputation. It should be recognized however that if properly controlled, residual stress may be very beneficial in extending the usefulness of various materials in many applications. Processes such as shrinking external jackets on tubes (used in the manufacture of large guns) or plastic prestressing provide examples of the control of residual stress to produce more favorable stress systems under load and more economical use of material.

Application of Theoretical Formulas

The various problems for which formulas are developed in strength of materials and elasticity are distinguished from each other by specification of the shape of a member, how it is loaded, and the initial state of stress. These conditions completely describe an individual problem and form the basis upon which theoretical formulas are developed. These conditions may be considered to be the hypothesis of the various theoretical stress formulas.

Before utilizing any formula, the designer must be certain that the conditions of his problem correspond to the hypothesis of the formula, at least within acceptable limits. Occasionally one is tempted to use a "handbook formula" without investigating its development and without comparing the conditions for which the formula was developed with the conditions of the problem at hand.

The hypothesis of a formula serves as the limit of its applicability; a formula can be used to solve only those problems which satisfy its hypothesis. When investigating the applicability of a formula, one should consider the following aspects of its hypothesis:

LOADING: How external forces are applied is, of course, of first concern.

1. *Static or Dynamic.* Dynamic loading may re-

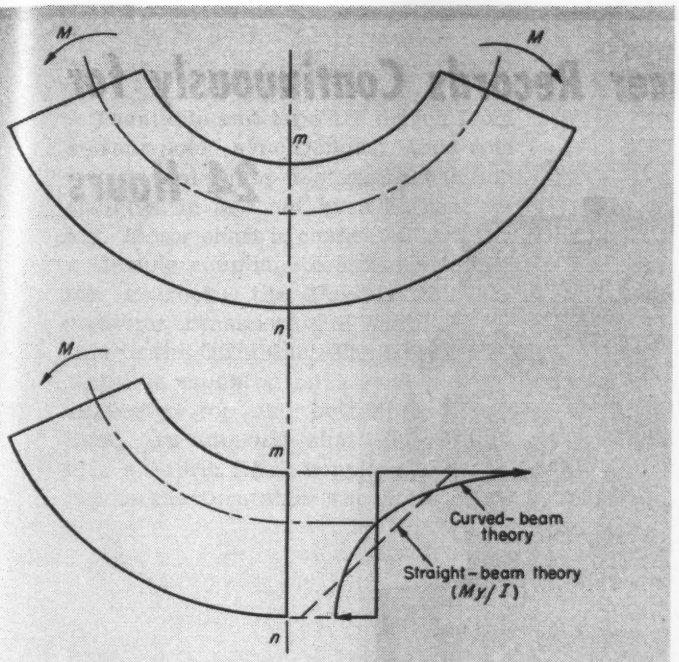


Fig. 23—Effect of initial curvature on the stresses within a beam

quire the use of "equivalent static loads" in order to satisfactorily analyze the case of impact, for example.

2. *Fundamental Type of Load.* The fundamental types of loading may be considered to be axial, bending, twisting, or shear. If the loading is more complex, it may often be separated into equivalent systems (via mechanics and Saint-Venant's principle) of the fundamental types and the principle of superposition applied to get the combined result. There are limitations to the use of superposition, however; the method is valid only as long as a linear relationship exists between the applied loads and their effects.[19]

3. *Points of Application and Distribution of Load.* Saint Venant's principle may allow extending the use of a formula to include various load distributions and points of application. In this connection it may be advantageous to point out that when the load condition is prescribed, certain limiting conditions may be implied that are not immediately obvious. This is the case, for example, in the development of the straight beam theory of flexure. The loading condition is given by stating that the beam is to be in pure bending. In order to satisfy the conditions of pure bending, the following must be true:

a. The resultant of all external forces acting upon the section of the beam to be analyzed must be a couple; thus, no resultant transverse or axial loads are allowed.

b. Bending must occur in the plane of the couple in order to avoid twisting in addition to bending. This will be the case only when the plane of the couple contains the bending axis of the beam. The bending axis is the longitudinal axis which intersects all transverse cross-sections of the beam at their shear centers.

SHAPE: The shape of a member determines to a great extent the distribution of stress within itself.

1. *Initial Form.* This is best classified by an example. If a relatively slender bar of given cross-section is subjected to pure bending, a linear stress distribution would result. If the same bar initially curved were subjected to the same bending moment, the resulting stress distribution would be hyperbolic as shown in *Fig.* 23. The "straight-beam" theory of flexure would give incorrect results for the latter case; the "curved-beam" theory would apply.

2. *Discontinuity of Section.* The member should be critically examined for points of stress concentration and suitable adjustments made to insure applicability of formulas.

3. *Cross-section.* The effect of cross-section may be readily appreciated if one compares the stress distribution within a rectangular shaft with the distribution in a circular shaft.

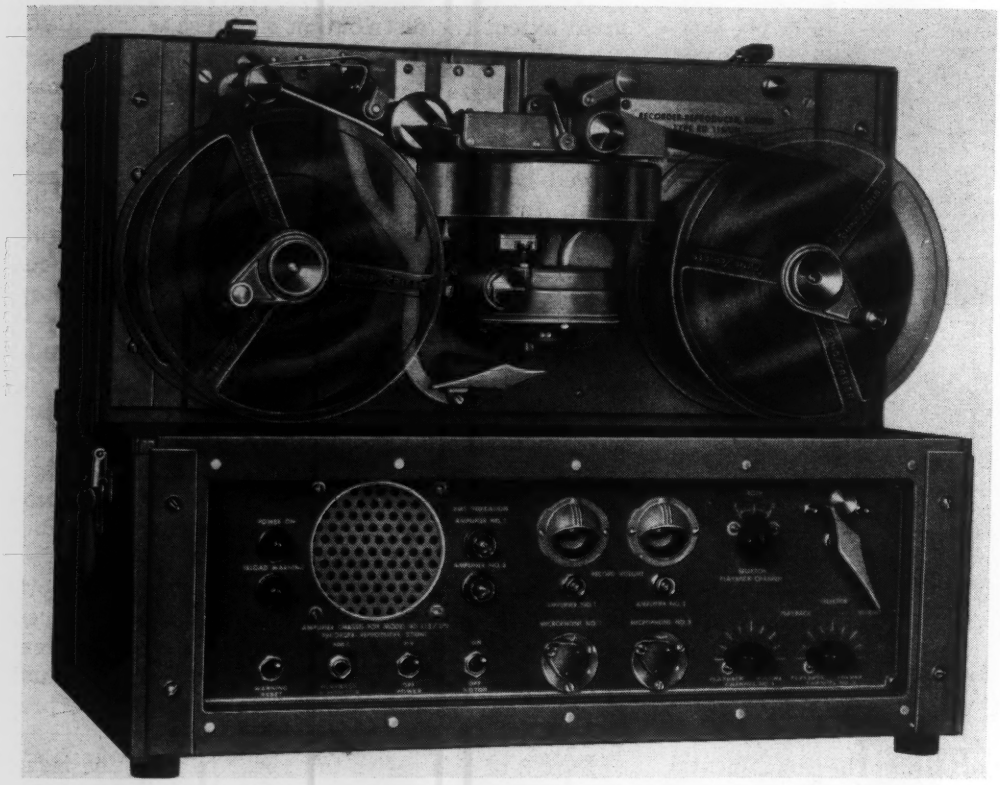
INITIAL STATE OF STRESS: Most formulas of both strength of materials and elasticity are developed on the assumption that there are no stresses present within the unloaded member. If residual stresses are present, these formulas will not predict the resultant stresses.

Part 3 of this series to appear in the June issue will discuss experimental methods of stress analysis.

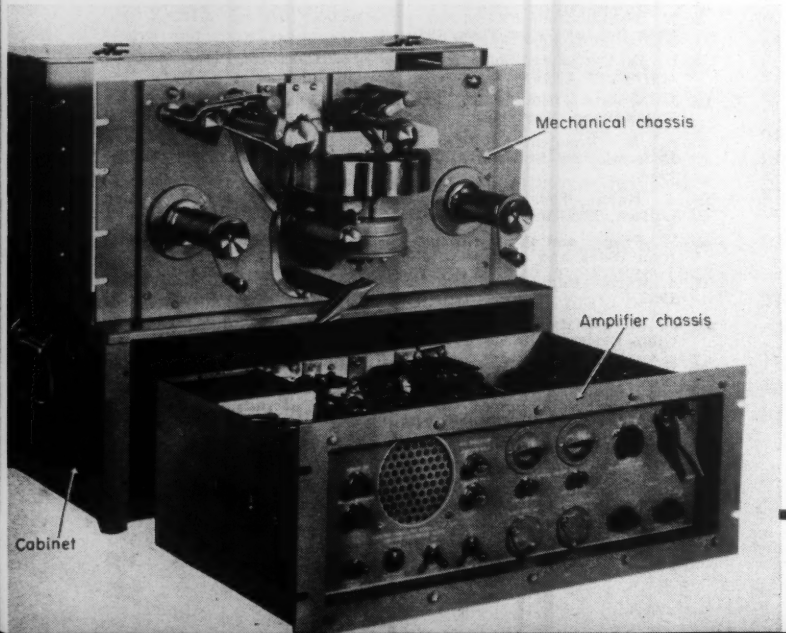
REFERENCES

1. S. Timoshenko and J. N. Goodier—*Theory of Elasticity,* Second Edition, McGraw-Hill Book Co. Inc., New York, 1951.
2. W. R. Mehaffey and C. O. Dohrenwend—"Dynamic Loading in Design," MACHINE DESIGN, June, 1943, Pages 99-104.
3. W. M. Murray—*Fatigue and Fracture of Metals,* Technology Press of MIT and John Wiley and Sons Inc., New York, 1952.
4. M. M. Frocht—*Photoelasticity,* Vol. 2, John Wiley and Sons Inc., New York, 1948, *Fig.* 1.16, Page 30.
5. Reference 4, *Fig.* 1.15, Page 30.
6. F. D. Murnaghan—*Finite Deformation of an Elastic Solid,* John Wiley and Sons Inc., New York, 1951.
7. J. B. Hartman and M. M. Leven—"Factors of Stress Concentration for the Bending Case of Fillets in Flat Bars and Shafts with Central Enlarged Section," *SESA Proceedings,* Vol. 9, No. 1, 1950.
8. K. Heindlhofer—*Evaluation of Residual Stress,* McGraw-Hill Book Co. Inc., New York, 1948.
9. H. D. Conway—"Some Problems of Orthotropic Plane Stress," *Journal of Applied Mechanics,* March, 1953.
10. J. Weerts—"Elastizitat von Kupferblechen," *Zeitschrift für Metallkunde,* May, 1933.
11. A. M. Freudenthal—*The Inelastic Behavior of Engineering Materials and Structures,* John Wiley and Sons Inc., New York, 1950.
12. A. Nadai—*Theory of Flow and Fracture of Solids,* Second Edition, McGraw-Hill Book Co. Inc., New York, 1950.
13. W. Prager and P. G. Hodge—*Theory of Perfectly Plastic Solids,* John Wiley and Sons Inc., New York, 1951.
14. J. Marin—*Engineering Materials,* Prentice-Hall Inc., New York, 1952.
15. C. R. Soderberg—"The Interpretation of Creep Tests for Machine Design," *ASME Trans.,* Vol. 58, 1936, Pages 733-743.
16. G. Sachs and C. H. Campbell—"Residual Stress in SAE X4130 Steel Tubing," *The Welding Journal,* Nov. 1941.
17. G. Murphy—*Advanced Mechanics of Materials,* McGraw-Hill Book Co. Inc., New York, 1946.
18. M. Hetenyi—*Handbook of Experimental Stress Analysis,* John Wiley and Sons Inc., New York, 1950.
19. S. Timoshenko—*Strength of Materials,* Part 2, Second Edition, D. Van Nostrand Co. Inc., 1941.

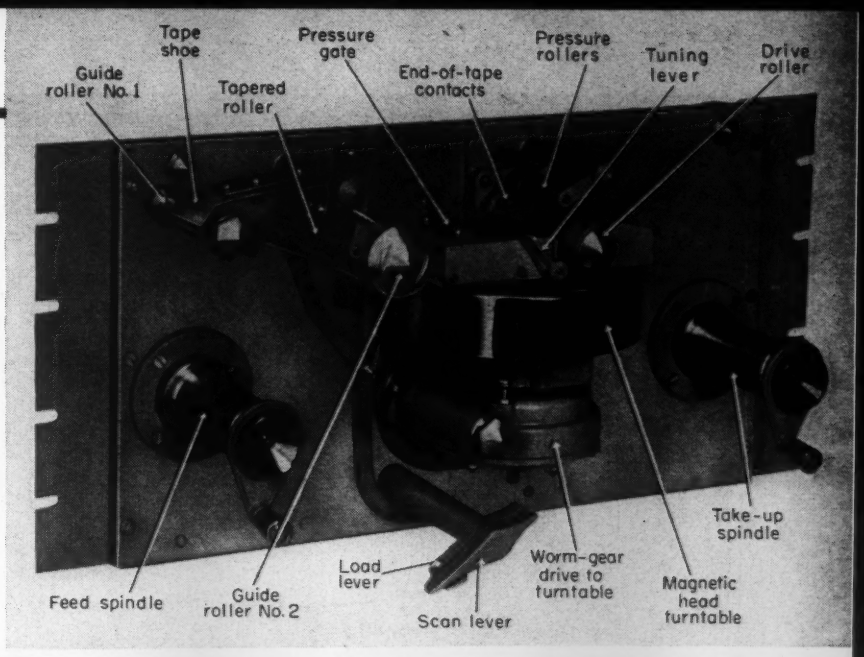
Recorder-Reproducer Records Continuously for 24 Hours



ONE 7-INCH DIAMETER plastic reel of 3-inch wide magnetic tape is used for 24 hours of continuous recording on the new Recorder-Reproducer of Soundscriber Corp. Depending on the particular model, one or two channels can be recorded; the two-channel model records both signals simultaneously. Recording medium is a red-oxide paper-backed magnetic tape fed at a linear speed of 9.28 inches per minute. Magnetic heads mounted in a turntable travel in an arc across the width of the tape at a scanning rate of approximately 4 inches per second; each of the two amplifier channels on the dual model records alternate sound tracks. The second channel is identified by a periodic low-level tone every few seconds. A time scale is printed on the back of the tape (wound toward the outside of the reel) to permit rapid place-finding, and a metallic strip cemented to the paper side of the tape 5 minutes before the end of the time period actuates a visible and audible signal to indicate that a tape change is needed.

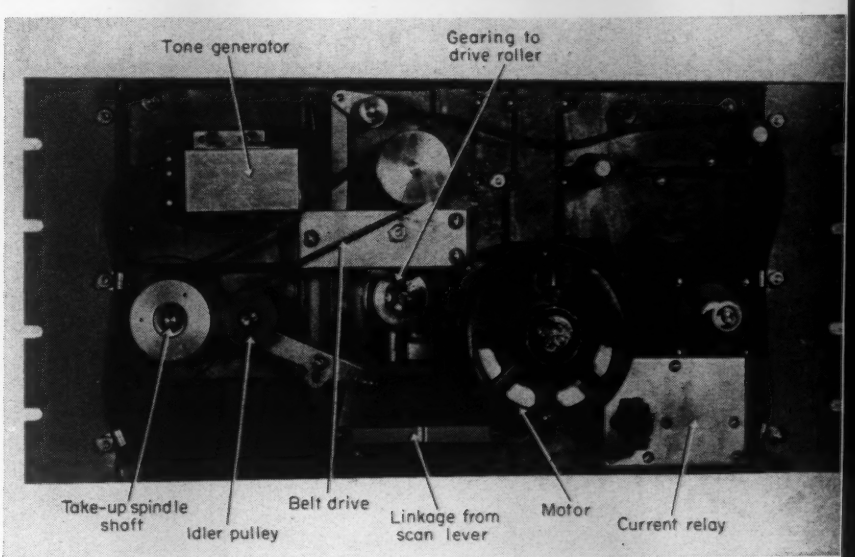


Amplifier chassis is a self-contained unit which can be mounted in a standard 19-inch rack. It contains all electrical components with the exception of the motor, magnetic heads, end-of-tape signalling contacts and the signal generator for channel-two identification; these are connected to the amplifier chassis by disconnect plugs and sockets. Similarly, the mechanical chassis is self-contained and designed to be mounted in a standard 19-inch rack.



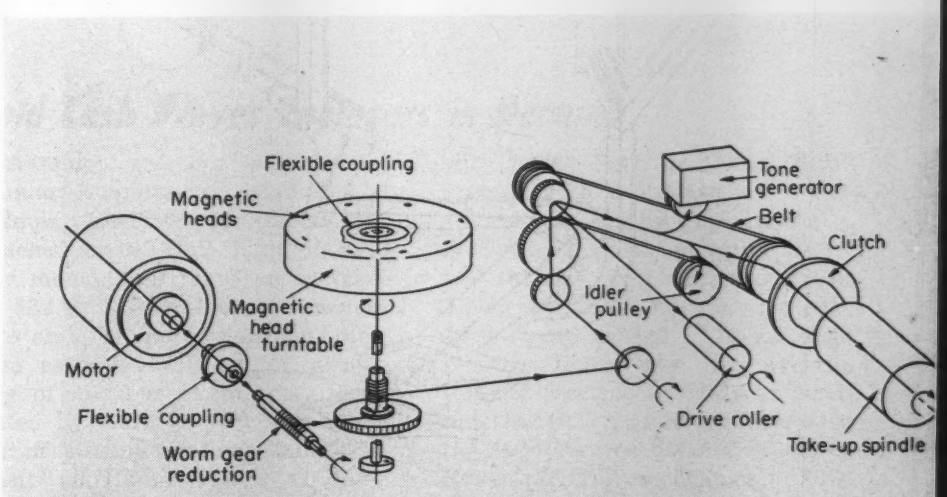
Turntable and tape are driven from a four-pole, synchronous, 1800-rpm motor containing a starting winding switched in and out by a current relay. Motor shaft is connected through a flexible coupling to a worm within the gearbox; the flexible coupling prevents transmission of motor vibration to the turntable. The fiber worm wheel is mounted on a hollow shaft supported top and bottom by bearings. An internal shaft is screwed into a fabric filter coupling connecting to the turntable; the bottom has a knurled circular plate fastened to the hollow gear shaft by a thumb screw. This arrangement permits easy replacement of the turntable or magnetic heads.

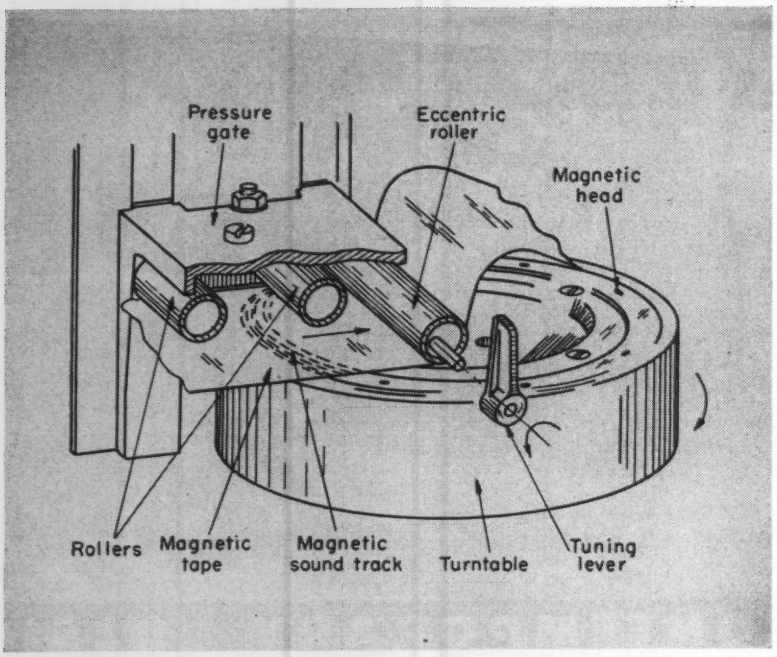
CONTEMPORARY DESIGN



Feed spindle is a free-rotating shaft mounted on needle bearings. Takeup reel is driven by a belt and pulley system actuated by an idler pulley that tensions the belt when recording or playing back. A friction slip clutch on the shaft of the take-up spindle shaft permits the spindle to run fast enough to keep the magnetic tape tight on the reel as it is pulled along by the tape drive roller.

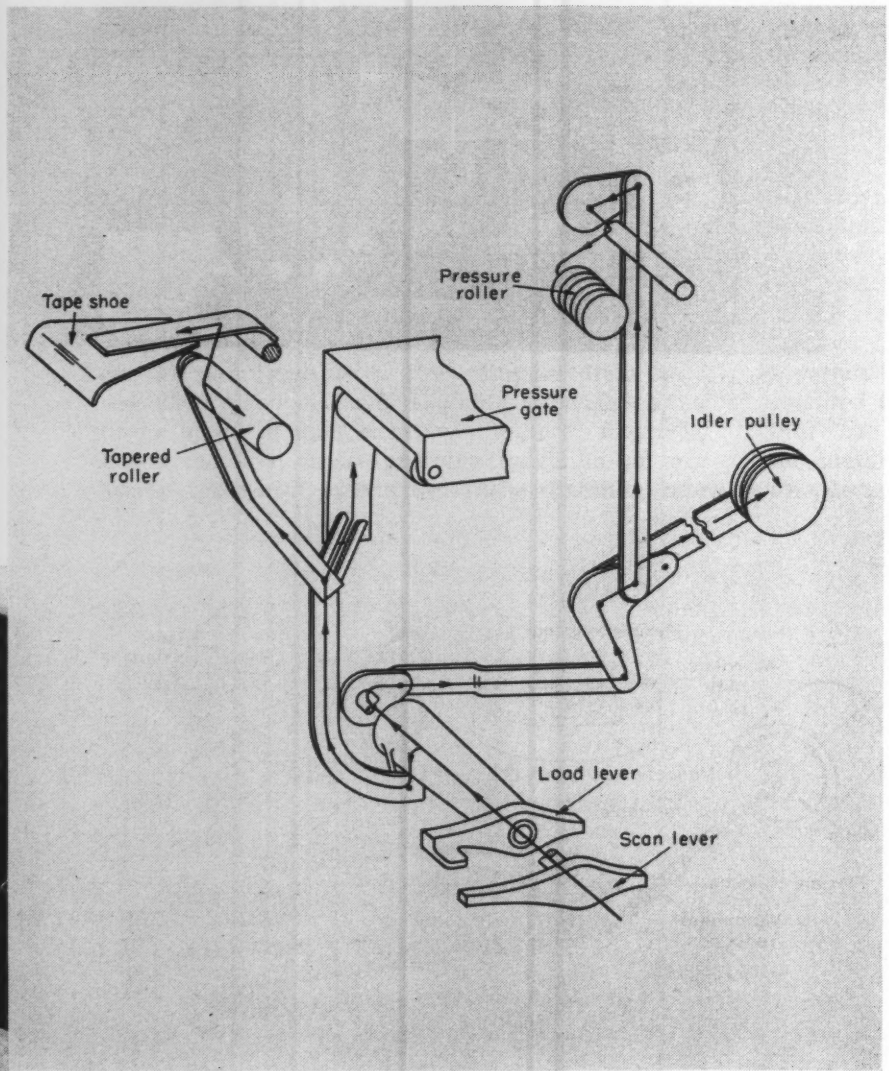
Developing a low-level periodic tone, the tone generator is also driven by the belt. Essentially, the generator consists of a coil of wire mounted in a permanent magnetic field, with a reed armature located in an air gap of the field. Magnetic flux is changed by vibrating the reed with a ratchet; the output voltage developed by the generator is applied to the output stage of the recording amplifier of channel two.





Eight ring type magnetic heads mounted in a circular turntable "scan" arcs across the tape. Heads are connected in the dual-channel model in two sets of four heads each, mounted alternately, so that each set is for one channel. Three silver-coated slip rings under the turntable provide the means for feeding the signal to the amplifier; one ring is common to both sets of heads. Tape is pressed against the magnetic heads by a flexibly hinged pressure gate held down by spring pressure. One guide roller is mounted off-center to provide a means for shifting the position of the tape relative to the magnetic heads to line up the sound tracks during playback.

CONTEMPORARY DESIGN



Magnetic tape is guided by a system of rollers from the feed reel over the magnetic heads to the takeup reel; the pressure gate presses the tape against the magnetic heads. Rubber pressure rollers, which press the tape firmly against the drive roller by spring pressure, are mechanically linked to the *scan* lever, as is the idler pulley. Pressure gate, tapered guide roller and tape shoe are linked to the *load* lever. When the levers are in counterclockwise position (as shown), the tape shoe, roller, gate and pressure roller are in the down or operating position, and the idler pulley takes up belt slack. Rotation of the levers clockwise approximately 180 degrees releases all units. In the operating position, the tape shoe forces the tape by spring pressure against the first guide roller (No. 1), and the tapered roller takes up slack in the variations in width of the magnetic tape. The third guide roller (No. 2) positions the tape before it goes under the pressure gate. For some functions, such as fast tape positioning, the *scan* lever only may be turned clockwise and the right-hand reel turned by hand at faster than normal rate.

Engineering NEWS ROUNDUP

Production Increases Lower Titanium Prices

Higher production and improved processing methods are the reasons given for recently announced reductions in the price of titanium mill products. The reductions as high as 14 per cent were announced by Titanium Metals Corp. of America and Rem-Cru Titanium Inc.

Despite the price reductions, there seems to be little danger of this light, highly corrosion-resistant metal replacing more widely used materials, except in applications demanding its properties, because of the still somewhat high price. Base price of billets and bars announced by one producer is $9.00 per pound, a reduction of 14 per cent from the previous price of $10.50 per pound.

Plastics Exposition May Break Exhibit Record

Last held in 1952, the 1954 National Plastics Exposition sponsored by the Society of the Plastics Industry is expected to have a record number of exhibitors. To be held at Cleveland's Public Auditorium from June 7 through 10 in conjunction with technical conferences, the Exposition is expected to have as many as 150 exhibitors.

Exhibitors presently signed up include molders; laminators; extruders; fabricators; reinforced plastics products manufacturers; film sheeting and coated fabrics processors; raw materials suppliers; machinery and equipment manufacturers; and tool, die and mold makers. More than 35 companies will be exhibiting for the first time at a plastics exposition.

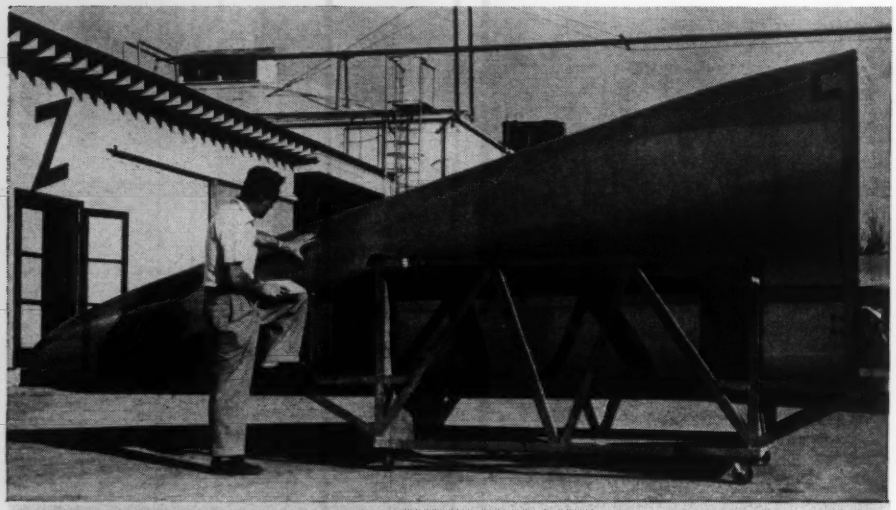
DOME CAR built of stainless steel seats 57 people in angled seats on the upper deck, 18 in an upper lounge and 28 in a lounge on the lower level. Cars are equipped with radio, wire recorded music and pneumatically operated doors. Both heating and cooling units are used in the car. Cooling units are rated at 20 tons. Special controls are used to regulate temperature in the dome portion. Special trucks developed by General Steel Castings are equipped with American Steel Foundries combination brakes which have brake shoes pressing on a disk attached to the wheel hubs in addition to the conventional shoes operating on the wheel tread. Built by the Budd Co. for Santa Fe Railway, this car and others like it will be put in service on the *El Capitan, Chicagoan* and *Kansas Cityan* trains.

Cold Cash Proves Engineers in Demand

Average starting salaries of January engineering graduates at Illinois Institute of Technology reached an all-time high of $373 per month this year—an increase of $32 or 9.3 per cent over a year ago and $11 more than last June. The average is based on a survey of midyear engineering graduates by Earl C. Kubisek, director of alumni relations and placement at Illinois Tech. Figures are for students receiving a bachelor's degree and planning to work a 40-hour week. All graduates who filed for placement left school with jobs. Each man had an average of 7.5 interviews.

Chemical engineering graduates received the most lucrative starting salaries, with an average of $394, compared to the January, 1953 figure of $327. Other engineering fields and the average salaries received by midyear graduates of 1953 and 1954 follow with the 1954 figures listed first: civil, $388 ($353); mechanical, $370 ($353); electrical $367 ($345), and industrial, $350 ($356).

Averages, based on salaries of combined June and midyear grad-



STINGER TAIL, molded from Fiberglas cloth and polyester resins developed by Bakelite Co. is said to cost one-fifth as much as conventional metal construction. Weight is two-thirds that of the metal equivalent. The monocoque honeycomb sandwich design developed by Lockheed Aircraft Corp., practically eliminates all stringers, frames, bulkheads and fittings. Used to house submarine-seeking devices on P2V bombers, the tail is made by Zenith Plastics

uating classes, in recent years follow: 1949, $282; 1950, $258; 1951, $295; 1952, $328, and 1953, $362.

Average starting rates for Illinois Tech engineering graduates are above the national average, according to Kubicek. "This is because many IIT students have working experience in industry prior to graduation," he explained. "They work with firms on the co-operative work-study plan during the summers, part-time while attending school or at other times before and during their college careers."

Reinforced Plastics Use To Reach New High in 1954

According to a recent estimate made by the Society of the Plastics Industry the pace of present annual increase in reinforced plastics is between 33 1/3 and 40 per cent per year. This estimate is based upon the use of polyester resins which are the traditional yardstick for measuring the use of laminates. Use of polyester resins, according to the SPI has increased from 800,000 pounds in 1947 to 26 million pounds in 1953, or 3255 per cent. Predicted use of polyesters for 1954 is 35 million pounds.

New developments predicted for 1954 include new resins which will maintain their strength when exposed to hot liquids and new synthetic reinforcing fibers. Use of reinforced plastics in trucks, farm equipment and station wagon components, and an increase in their use for metalworking tools such as dies is also forecast.

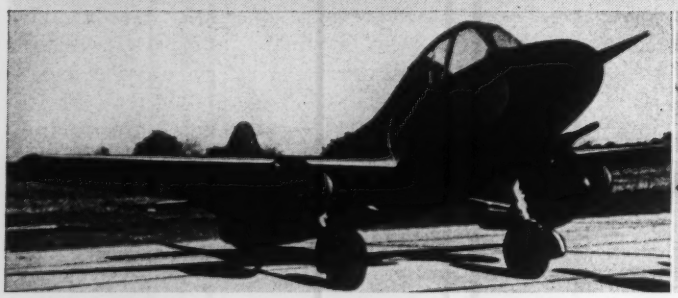
Research and Training Atomic Reactors Available

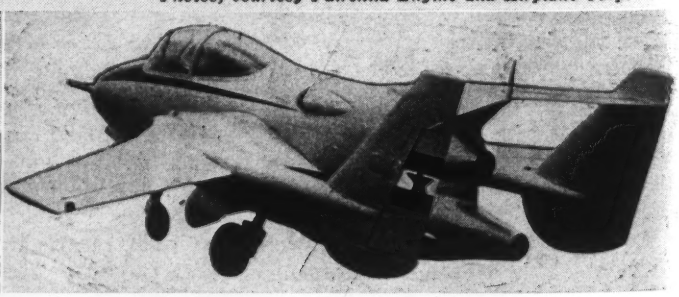
In view of a rising tide of interest among universities and other research institutions in acquiring reactors, the AEC has adopted a uniform policy for dealing with institutions requesting the loan of fissionable material for use in reactors for independent research and training. Reactor technology has advanced to the point where the Commission believes it is feasible and in the national interest to permit a few to be built in universities and research institutions. Designs are now available which provide simplicity, safety, and some predictable operating characteristics at a cost within reach of some universities.

Fissionable material is available

YUGOSLAV JETS: 451M, left and 452M, right, are Yugoslav designed and constructed jet aircraft. Both are powered by two French *Palas* engines of approximately 350 pounds thrust. The 452M flew for the first time in July, 1953. A prone position 451M is also being built

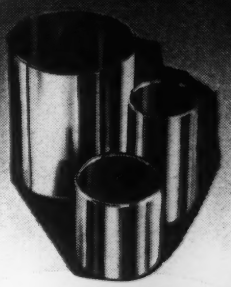
Photos, courtesy Fairchild Engine and Airplane Corp.

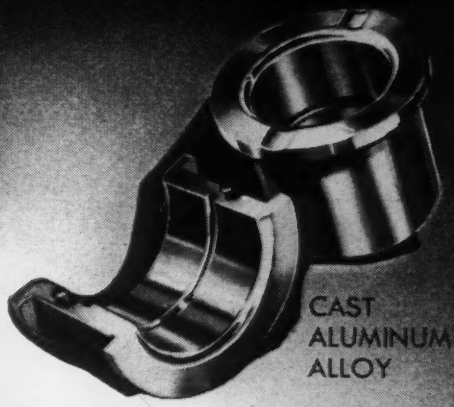




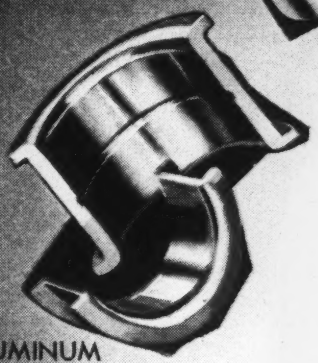
JOHNSON B BEARINGS
Sleeve-Type

SHEET BRONZE


BRONZE ON STEEL


CAST ALUMINUM ALLOY

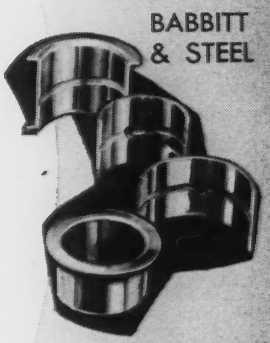
for Every Shaft


ALUMINUM ON STEEL

WHEREVER a shaft turns there is probably an application for a Johnson Sleeve Bearing. The range of types and sizes is the widest on the market. Johnson Bearings are used in industrial equipment, automotive, aircraft and transportation equipment, electrical equipment, farm machinery, earth-moving equipment . . . in fact, wherever a shaft turns. They are available in standard stock bearings or made-to-order for specific applications. Johnson engineers will gladly consult with you on your bearing problems. Write today.

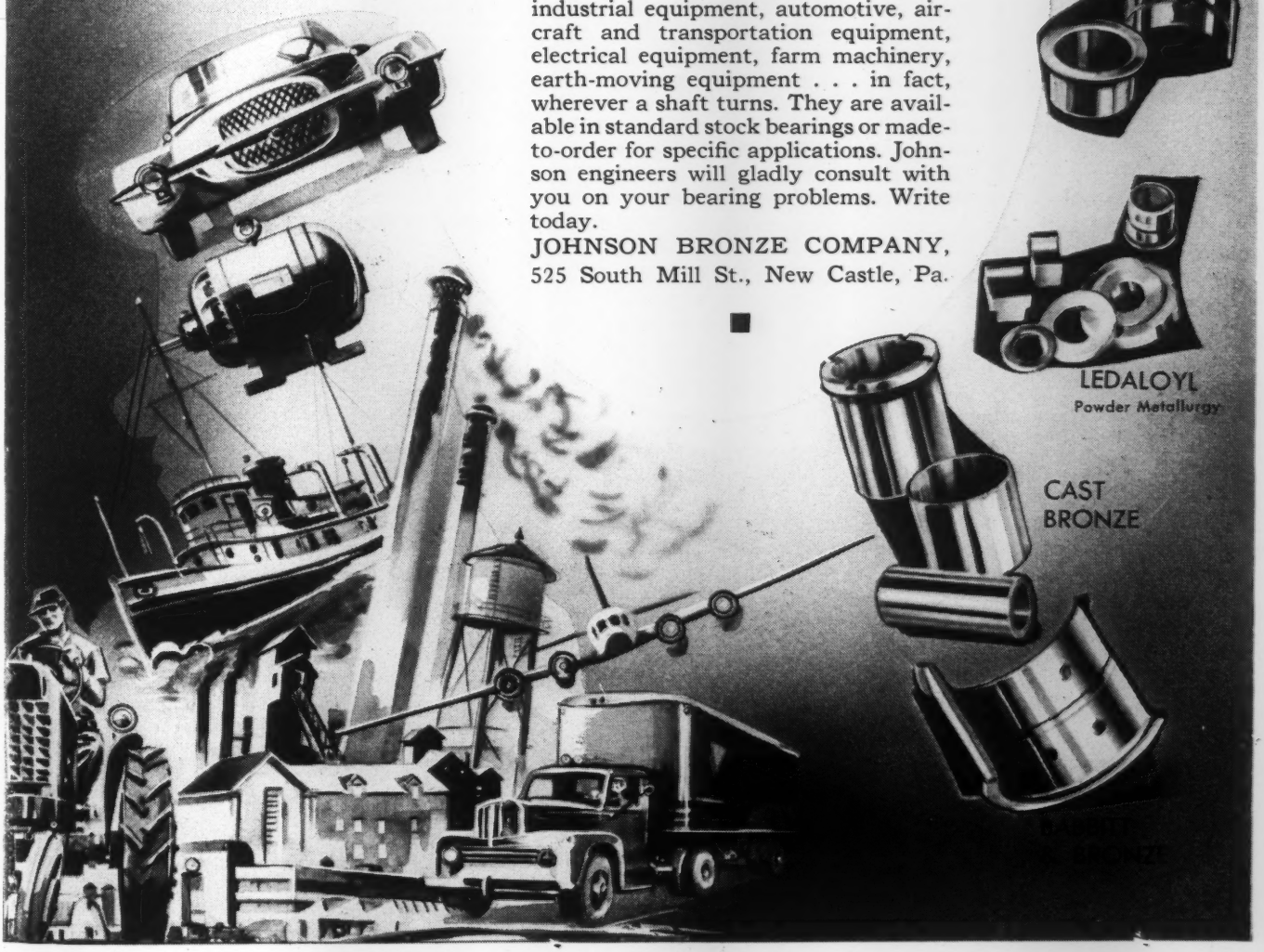
JOHNSON BRONZE COMPANY,
525 South Mill St., New Castle, Pa.

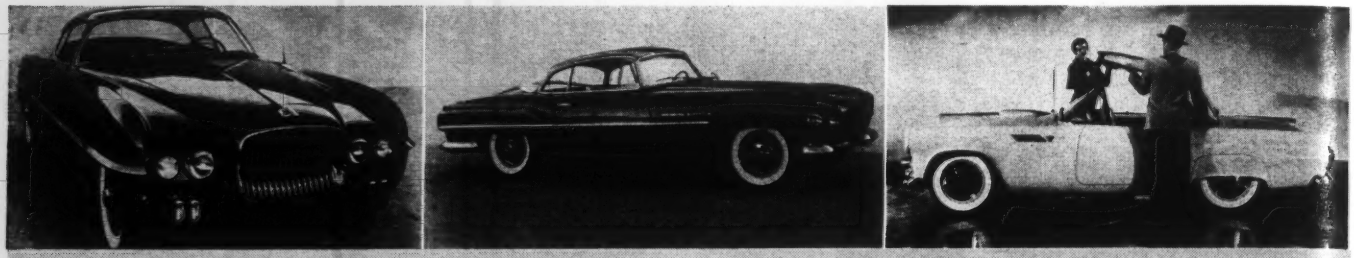
■


BABBITT & STEEL

LEDALOYL
Powder Metallurgy

CAST BRONZE





FIREARROW, THUNDERBIRD and EXPLORER are the imaginative titles given these three creations of the automotive manufacturers. Firearrow, left, and Explorer, center, were handcrafted by Ghia of Turin, Italy for the Dodge and Plymouth Divisions of Chrysler Corp., respectively. Thunderbird, right, was made by Ford of Detroit, Mich. Both the Firearrow and Explorer were designed and built to test public reaction to their styling. Thunderbird is to be placed in production in the fall. All-steel body, 160-hp engine, adjustable telescoping steering column, tachometer, removable hard top plus folding convertible top and overall height of only 51.5 inches are all part of the Thunderbird story. Hard top can be removed easily by two people

in sufficient quantity that the Commission may loan it for independent reactors without charge for rental or processing when this material is not in immediate demand for military and other uses by the Commission. The Commission must be assured that the institution has a financial plan which provides for the construction and operation of the reactor and its design and operation will be in the hands of technically competent people. Further, the reactor must be used in a well planned research program which may be expected to contribute significantly to the training of students in nuclear research, engineering and other fields of science.

The Commission may consider partial support of the cost of construction of reactors at nonprofit institutions, but will not commit itself to supporting the costs of operation nor the costs of buildings to house them.

In line with this policy, the AEC has made a loan of 999 grams of U^{235} to North Carolina State College and has assured Pennsylvania State University that fissionable material will be made available when its reactor is constructed.

Also very timely is an announcement made by the Babcock and Wilcox Co. regarding commercial availability of reactors expected to produce in excess of 100 kilowatts.

The reactor, a liquid fuel type, is based on a modification of a Los Alamos design conceived by Dr. Lyle Borst of the University of Utah and uses concentrated uranyl sulphate as fuel. Its cost is said to be well within reach of any university or company engaged in atomic energy research.

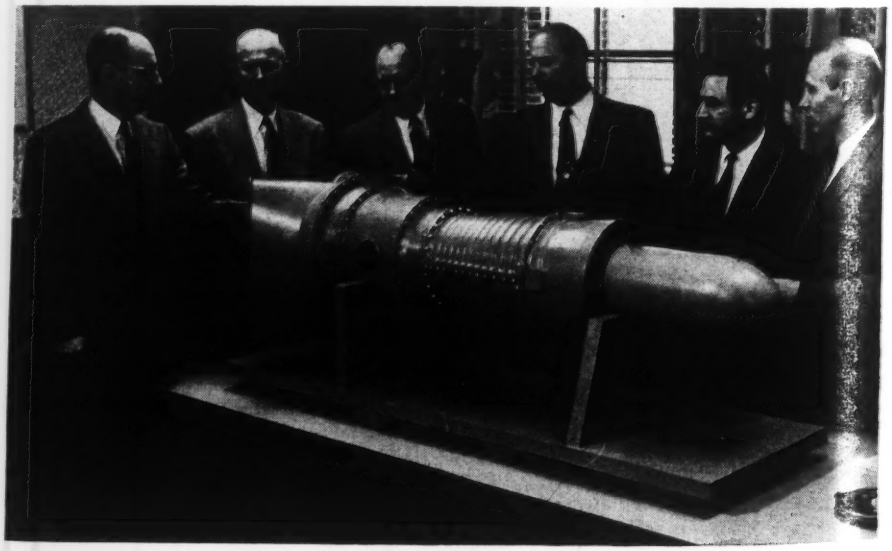
Small Gas Turbine Developed for Helicopters

A "baby" gas turbine, designated the XT-58, is being designed for the Navy's Bureau of Aeronautics. Though comparable in size to conventional piston engines used in family automobiles, the turbine is expected to be from six to eight times as powerful. Intended primarily to power helicopters, the engine is being developed by General Electric's Small Aircraft Engine Dept.

Predicted advantages of the turbine engine include weight reduction, quieter and smoother operation, and easier installation. Additionally, preliminary studies indicate that oil consumption will be decreased and cooling will be simplified. Fuel will be the inexpensive type usually used.

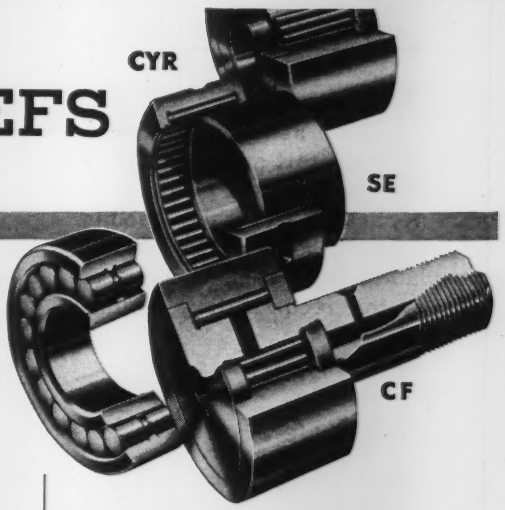
Modifications of the engine are

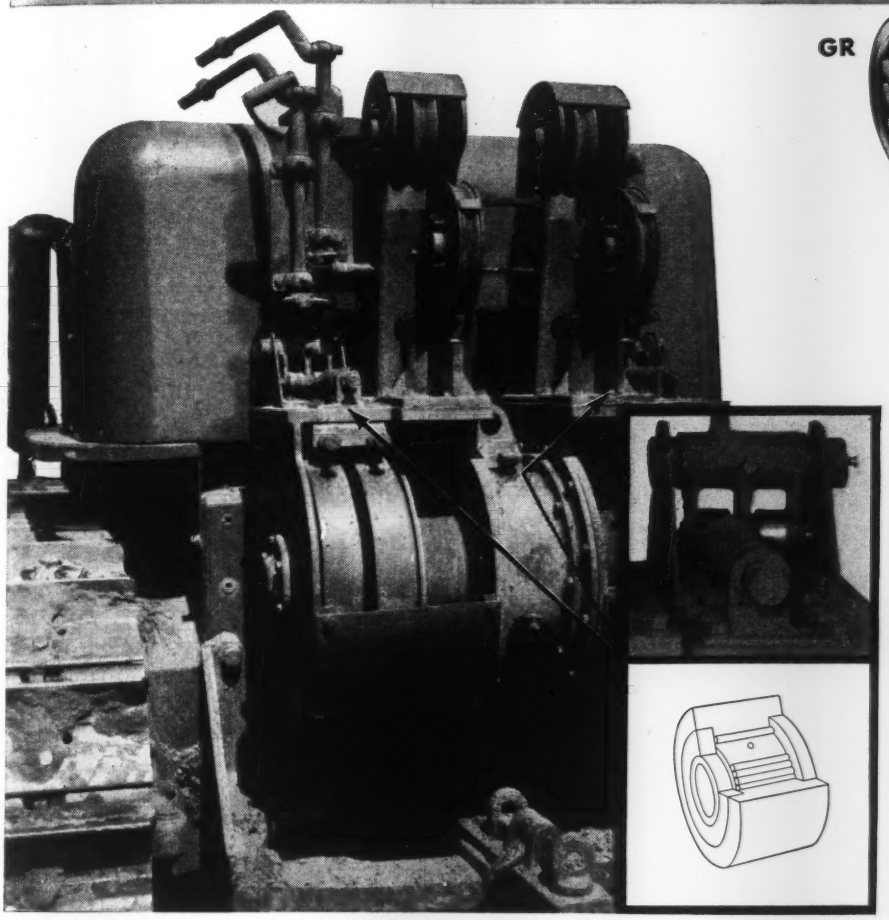
Mock-up of small gas turbine for helicopter use being inspected by executives of General Electric Co.'s Small Aircraft Engine Dept.



(Advertisement)

McGILL BEARING BRIEFS



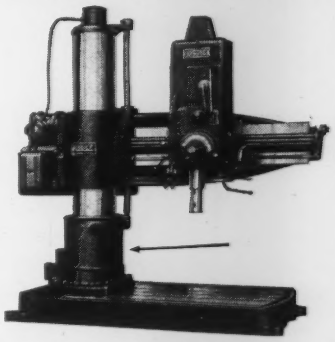


MULTIROL® CYR Bearings HELP PROVIDE "POSITIVE ACCURATE CABLE CONTROL" on Gar Wood Cable Control Units

It takes dependable, precision bearings to achieve the "fast, accurate control" featured in Gar Wood Cable Control Units. That's why Gar Wood has standardized on Multirol CYR Bearings as cam rollers on the control arms. The Model 281 unit uses 4 CYR bearings to enable precise, frictionless adjustment of control cables on each of two drums that handle a scraper or dozer blade. CYR Bearings have a thick outer race section to withstand the heavy shock loads encountered in such cam applications. They help make the Gar Wood Cable Control a rugged, hard-working unit that stops and starts smoothly.

Multirol CYR Bearings are built to provide longer life and greater efficiency in cam operations. They are labyrinth sealed by roller retaining end plates tightly fitted and secured to the shoulders of the inner ring. Yoke mounting is possible where desirable on shaft sizes ranging from ¼" to 1¼" for corresponding roller diameters of ¾" to 4".

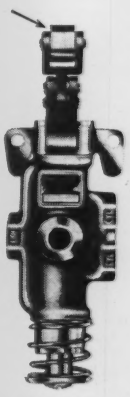
FOSDICK DRILL HEADS POSITIONED BY CYR BEARINGS



Fosdick Machine Tool Company uses Multirol CYR Bearings to provide rigid and accurate support between inner and outer columns of this Hydraulic Radial Drill. The CYR Bearings act as guide rollers between columns to provide precision positioning of the drill head.

CYR BEARINGS REDUCE FRICTION ON VALVAIR VALVES

Changing the cam roller on this Valvair 4-way cam operated valve to a Multirol CYR Bearing reduced friction on the cam plate and eliminated elongation of the hole in the cam arm. Since replacing friction type rollers with CYR Bearings, they have never had occasion to replace either the cam roller or the cam arm.



BEARING SELECTION GUIDE
A new 140-page Bearing Selection Guide, complete with 30 pages of vital engineering data, has been released by the McGill Manufacturing Co. Ask for Catalog No. 52.

McGILL® —Precision Bearings
McGILL MANUFACTURING COMPANY, INC.
200 N. Lafayette Street, Valparaiso, Indiana

expected to be suitable for use in fixed-wing aircraft as either turboprop or turbojet power plants. Possible applications of these modifications would be in military training planes and as booster power sources for reciprocating engine-powered planes.

Materials Conference To Be Held in May

Chicago's International Amphitheater will be the site of the second Basic Materials Conference and Exposition to be held May 17-20. Exhibitors will be producers of basic materials. It has been said that there are more than 25,000 different materials currently in use and that more are being added every month.

Purpose of the Conference is to acquaint executives and engineers concerned with product development with relative advantages of various available materials. Industrial applications of new materials developed for use in rockets and guided missiles will be the subject of one of the sessions. Another session will explain how to establish a materials department for development of new product ideas.

Sponsors of the Exposition and Conference include scientists, researchers, engineers and executives from both industry and government organizations. Advanced registration cards and further details may be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Internal combustion engine design with special emphasis on the analytical approach to performance, development and design problems will be covered in a special program from June 15 through 25 at the Massachusetts Institute of Technology. This special summer program is designed primarily for engineers responsible for designing and developing improved engines and for teachers of these and related subjects.

SUPERSONIC DELTA: This photograph and others of the F-102, Air Force's first all-weather supersonic interceptor, were recently made public for the first time. Now undergoing tests at Edwards Air Force Base, the delta-wing craft was built by Consolidated Vultee Aircraft Corp.

Professor C. Fayette Taylor, professor of automotive engineering and director, Sloan Laboratories for Aircraft and Automotive Engines at M.I.T., is director of the course.

Government Reduces Copper Requirements

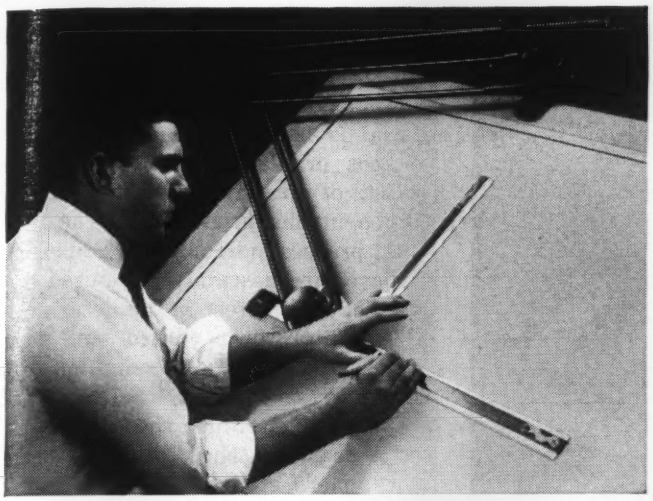
Percentages of copper and copper-base alloy products which producers have been required to reserve for military and atomic energy rated orders have recently been reduced by amendment of Business and Defense Services Administration Order M-11A.

According to BDSA officials, reduction in percentage reserved for military and atomic energy orders reflects reduced copper and copper-base alloy requirements for such purposes during the second quarter of 1954. The percentage cut does not apply to military ammunition cups and disks, nor to copper-base alloy powder mill products. Space for these products will continue to be reserved at the producer's plant in accordance with production directives issued by BDSA under the Defense Materials System.

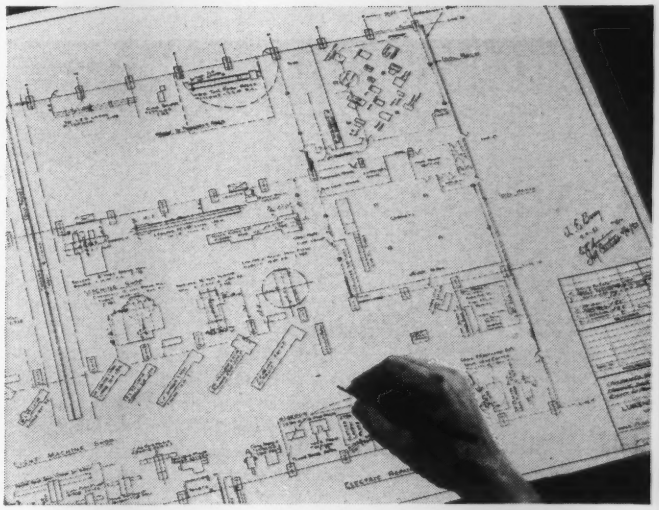
Mill space reserved for copper wire mill products for second quarter delivery to meet military orders is reduced from 20 to 16 per cent. Space reserved for copper foundry products and unalloyed copper powder mill products is reduced from 27 to 15 per cent.

The following changes are made in reserve percentages for unalloyed brass mill products: Plate, sheet, strip, and rolls, from 15 to 10 per cent; rod, bar shapes and wire, 16 to 11 per cent; seamless tube and pipe, 11 to 8 per cent. Alloyed products: Plate, sheet, strip, and rolls, 26 to 16 per cent; rod, bar, shapes, and wire, 32 to 14 per cent; and seamless tube and pipe, 55 to 38 per cent.

The reduced set-aside percentages are applicable to authorized controlled material orders received by brass mills, copper wire mills, pow-



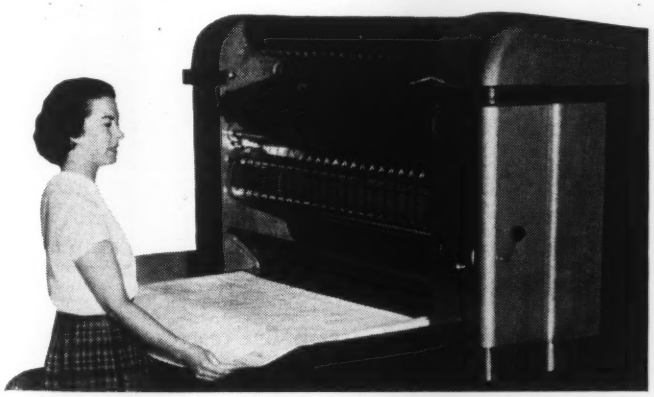
Instead of starting all over again



. . . he begins here

Here's how the Lukens Steel Company, Coatesville, Pa., uses Kodagraph Autopositive Paper to eliminate retracing in preparing flow diagrams and piping layouts.

THESE diagrams and layouts must also show the floor plans and fixed equipment installations of the departments involved. But instead of retracing this information from the basic plant layout drawings, Lukens Steel simply reproduces the drawings on Kodagraph Autopositive Paper—gets *positive, photographic* duplicate tracings directly. This gives the draftsman a tremendous head start . . . for he only has to add the new detail to the Autopositive print . . . *and another job is done instead of being barely begun.*



Low-cost Autopositive reproductions are made this easily at Lukens Steel:

Kodagraph Autopositive Paper is exposed with the drawings in a direct-process machine . . . and processed in standard photographic solutions. A fast, convenient room-light operation that produces positive photographic intermediates *without a negative step . . . without a darkroom.* These intermediates, in turn, assure highly legible prints.

Lukens Steel Company also uses Autopositive Paper *to produce print-making masters* from vendor blueprints; *to simplify filing,* by combining small vendor drawings on Autopositive intermediates in the standard Lukens drawing size; *to get low-cost protection* for original drawings which must be sent out of the plant.

Kodagraph Autopositive Paper

"THE BIG NEW PLUS" in engineering drawing reproduction.

——————MAIL COUPON FOR FREE BOOKLET——————————————————

19

EASTMAN KODAK COMPANY
Industrial Photographic Division, Rochester 4, New York

Gentlemen: Please send me a free copy of your illustrated booklet, "Modern Drawing and Document Reproduction."

Get the full story on the sensational line of Kodagraph Materials which you, or your local blueprinter, can process easily, at low cost. Write today for free booklet.

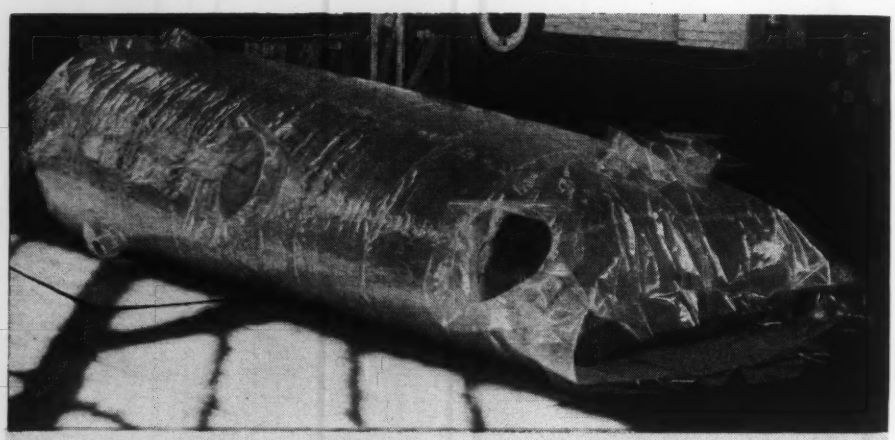
Name_____ Position_____

Company_____

Street_____

City_____ Zone_____ State_____

Kodak



WELDED MEMBRANE of Kel-F resembles a sea monster with its gaping maw, but is actually a tank liner manufactured by U. S. Stoneware and used to prevent corrosion of a steel tank. Recent development of a method for welding the plastic film permits fabrication of envelopes such as this complete with outlets. Two vinyl or polyethylene bags are also used to protect the 0.005-inch thick membrane from mechanical damage

der mills, and brass and bronze foundries calling for delivery after March 31, 1954. Present percentages continue to apply for military orders calling for delivery prior to April 1, 1954.

Atomic Tea Kettle

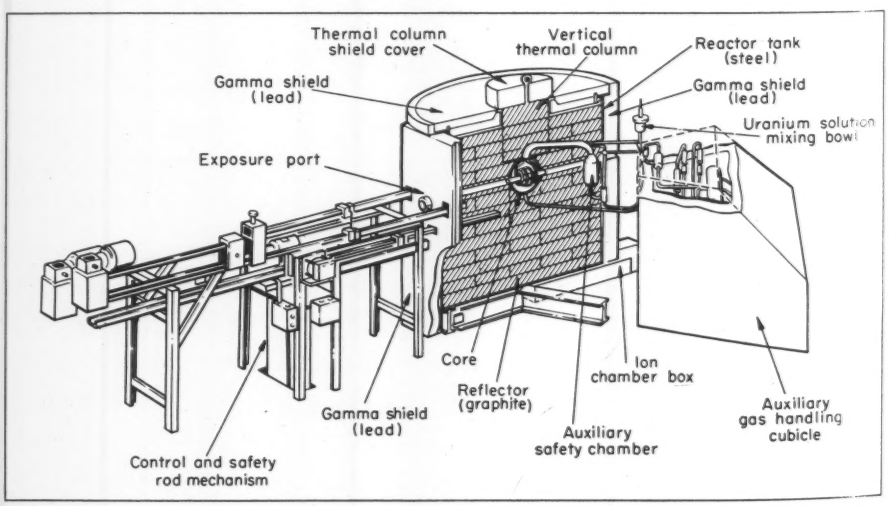
Developing 100 watts of power, a new reactor is said to be unique in that it is the largest unit of its type to operate with a closed cycle. Known as a "tea kettle" or water-boiler type reactor, the reactor is designed to retain all radioactive fission byproducts in the unit instead of exhausting them into the air. Byproducts are processed in the unit and returned to the reactor core. It is possible for the reactor to operate for 10 years without refueling. Built by North American Aviation Inc. for the Atomic Energy Commission, the reactor is operated by the California Research and Development Co.

Nuclear research scheduled for the new reactor will include fundamental studies as well as test work with various materials and components being studied for possible application to atomic energy equipment and processes. At 100 watts of power the unit will produce a concentrated field of neutrons to bombard and irradiate test materials. If required, the reactor can be converted to operate 2000 watts of power to produce an even greater neutron "flux" or stream of neutrons sometimes required for more advanced or more critical experiments.

The reactor will be fueled with uranyl sulfate, enriched in fissionable uranium 235, in a water solution. About 4 gallons of this material is housed in a steel sphere, 1 foot in diameter. A cylindrical stack of graphite bars to reflect the neutrons produced by the fission process, surrounds the sphere. This entire assembly is housed by a steel tank 5 feet in diameter and 5 feet high. Two control and two safety rods, made of cadmium and boron, run through the tank to the sphere. Because these rods absorb neutrons, their presence near the sphere stops the fission process. When the rods are withdrawn the Uranium 235 solution begins the atomic fission process producing neutrons and other nuclear radiations. Access holes leading through the tank to the sphere permit the bombardment of test samples by neutrons and other radiations. During ordinary operation, only the two control rods are used to start, stop and regulate the fission process. The two safety rods are designed to automatically shut off the reaction if required.

Inherent characteristics of the design of a water boiler reactor make it virtually impossible for the fission process to "run away." If an uncontrolled fission occurs, the heat of the reaction in the water solution will stop the process before damage can be done. The safety rods can be used with the same effect. In addition to the natural safety chamber system is a further safeguard. A completely

Artist's sketch of new atomic tea kettle or water boiler reactor. No exhaust or fumes are emitted by reactors of this type



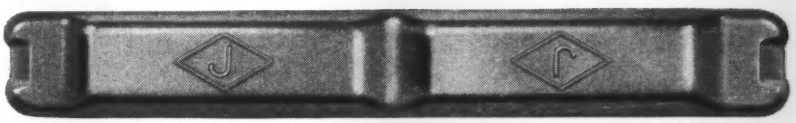
Specific Gravity is Important

To Your Casting Costs

ALMAG 35

ALUMINUM ALLOY

. . . with a Low Specific Gravity of 2.62, Gives You More Castings Per Pound



Because Almag 35 weighs less than standard aluminum alloys, it contains more cubic inches of metal per pound (s.g. 2.62).

This is an important saving in your foundry operations because it means you can get more castings per pound of Almag 35 than with most other aluminum alloys.

Reduced freight and handling costs also add up to make Almag 35 the most practical aluminum alloy for high structural and finish requirements.

Before you specify any alloy, ask for Almag recommendations.

Covered by U.S. *Patents* Nos. 2564044, 2628899, 2583473. Other Patents Pending

WILLIAM F. JOBBINS INCORPORATED

AURORA, ILLINOIS

P. O. BOX 230

new development, the safety chamber provides a method of reducing the amount of fissionable material in the sphere to less than a critical mass, or to an extent that fission can occur. This is accomplished by a percolating process. If fission gets beyond a certain rate, gas bubbling through the uranyl sulfate solution carries the material into the auxiliary safety chamber and away from the fission sphere, in the same manner that steam percolates water over coffee in the family coffee pot.

Annual meeting of the American Society for Engineering education will be held June 14-18 at the University of Illinois. More than 80 conferences will be held dealing with such matters as professional status of engineers, accreditation of engineering colleges, improvement of teaching and the interrelation of university, industrial and governmental research.

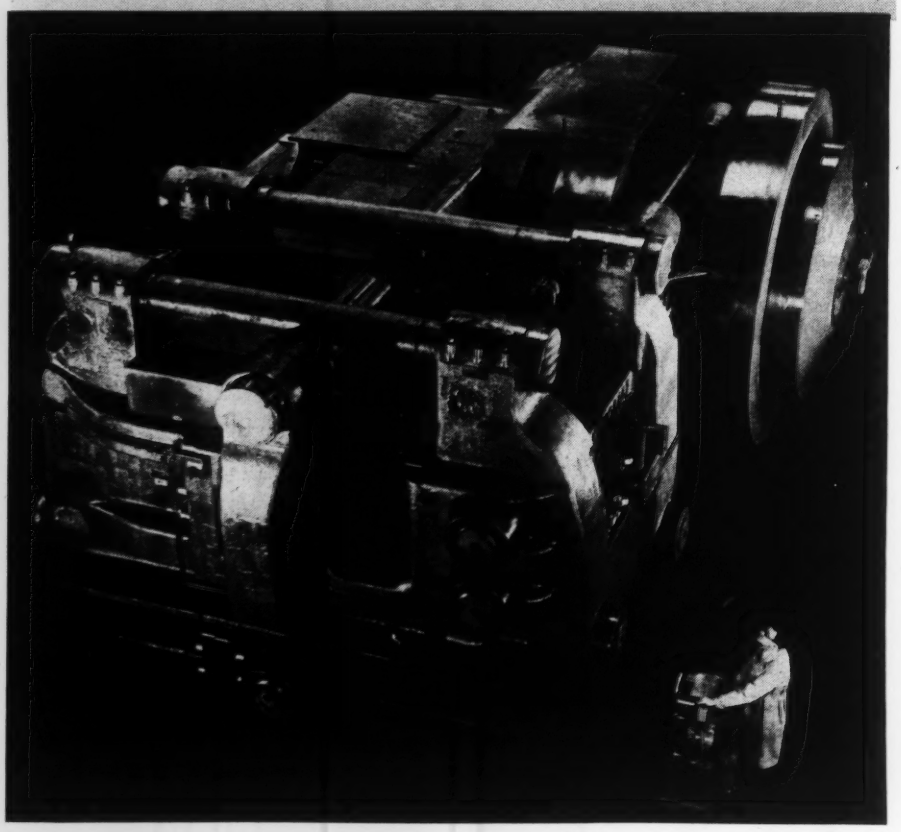
Stainless Steel Hits One Million Tons

Annual production of stainless steel ingots rose above one-million tons for the first time in 1953, American Iron and Steel Institute reported recently. The preliminary figure is 1,015,303 net tons compared with the previous record of 933,730 tons in 1951, 1952 output having been 930,164 tons because of the long strike.

Since 1946, the output of stainless increased 84 per cent, as of the close of 1953. Meanwhile, the total steel output increased 67 per cent. As compared with 1937, stainless steel output increased about 6½ times while total steel output approximately doubled.

Greatest tonnage among manufacturing users last year went to the automobile industry. Other leading uses were in household goods, industrial equipment and aircraft. Construction and military uses took substantial quantities, and there were many other users, such as restaurant kitchens, railroad cars, hospital equipment and radio and electronic devices.

GIANT FORGING MACHINE is said to be the world's largest of the horizontal type. Weighing nearly 1 million pounds or 500 tons, the machine measures approximately 15 feet by 12 feet by 12 feet high. To be used for forging components for military and commercial aircraft it is powered by a 300-horsepower motor. National Machinery Co. designed and built the behemoth for Tube Turns



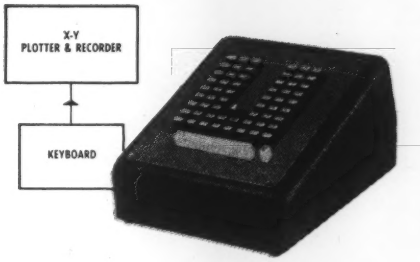
Holes Sent By Phone Lines

Rapid duplication of punched cards between remote points thousands of miles apart is now possible with a new punch card transceiver that operates over regular telephone circuits. Developed by IBM, the machines, when linked by telephone lines, can transmit and receive sixteen card columns of data every second, and four separate transmittals can be sent simultaneously over one wire.

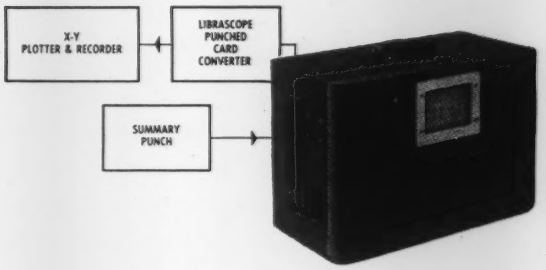
After each card is completed, the transmitter sends a signal to check on the accuracy of the holes produced by the receiver. Upon receiving a favorable reply, the transmitter proceeds to the next card.

Transmission of accounting data from branch offices or a plant to company headquarters, or transmission of data from a remote laboratory to a central electronic computer is now possible. A switch in the machine also permits voice transmission over the telephone circuits connecting the transmitting and receiving units.

Carter Achievement Awards designed to promote progress in the field of hydraulics and pneumatics have been announced by J. Carter Miller, president, Carter Controls, Inc. Entries should consist of any new, unique or unusual application of one or more pneumatic or hydraulic cylinders which can be



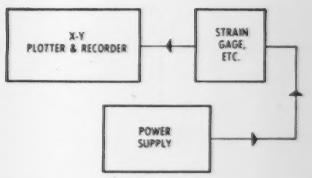
DECIMAL KEYBOARD: Consists of a three-decimal bank for each axis with associated plus-minus keys. Depressing plot bar initiates plot and clears keyboard automatically. Also manual clear button. Size: 8½ x 11 in., Weight: 12 Lbs.



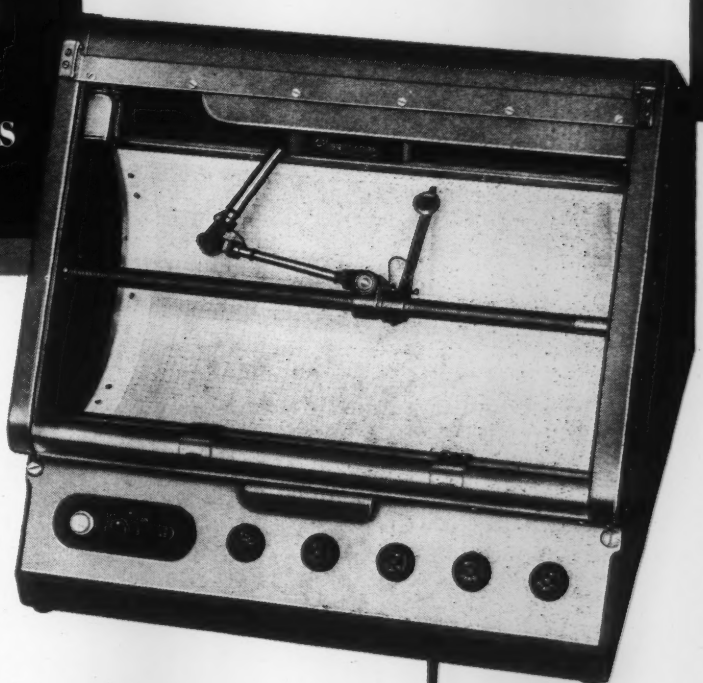
PUNCHED CARD CONVERTER: Converts punched card data to an analog form suitable for input to X-Y Plotter from Gang Summary or Reproducing punches. Display Monitor. Total tube complement 26 tubes.

X-Y plotter and recorder

simplified recording of two independent variables with greater selection of input devices



D.C. INPUTS: 5 millivolt full scale sensitivity on both axes. Infinite input impedance for signals to .5 volts. 2 megohms input impedance above .5 volts.



A compact, desk-size unit that accepts either analog or digital inputs. Standard digital converters: Decimal keyboard, Decimal punched card, and Binary for Computer Outputs. Handles remote mechanical shaft rotations directly without modification. Modifications available to customer specifications. Full chart visibility allows observer to view curve generation at all times. Unique pen travel for fast, dependable performance. Write for full catalog information.

DESCRIPTION:
Desk or Rack Mounted
(RCA or RMA)
Accuracy: .1%
Weight: 70 lbs.
Uses Standard Graph Papers:
11" x 16½", or 8½" x 11"
Power Consumption:
150 watts, 115 volts, 60 cycles

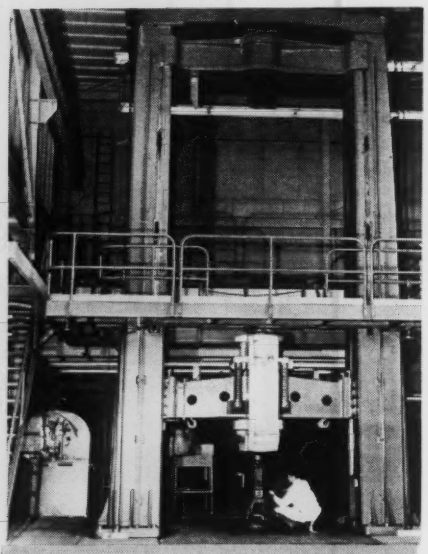
Engineers, physicists and mathematicians in search of interesting assignments, rapid advancement, and job security are requested to write Dick Hastings, Personnel Director.

Computers & Controls

LIBRASCOPE

A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

LIBRASCOPE, INCORPORATED 1607 FLOWER STREET, GLENDALE, CALIFORNIA



FREIGHT-CAR SIZE testing machine is being used to calibrate a dynamometer coupler here, although it could put the squeeze on an entire box car. The 1 million-pound capacity machine is 27 feet high, has 10-foot clearance between columns and a 60-foot base structure. Used to test railroad car truck side frames and bolsters, couplers, yokes, draft gear, journal boxes, etc., the Baldwin-Lima-Hamilton machine is installed in the Technical Center of National Malleable and Steel Castings Co.

shown to be of benefit in the form of lower costs, increased output, etc. Details and entry blanks may be obtained by writing Carter Achievement Awards, Carter Controls, Inc., 2800 Bernice Road, Lansing, Ill. The competition closes December 31, 1954. Winners will be announced in April, 1955.

Industry Can Help Make Better Engineers

"Industry and technical schools share a common interest in preparing the student engineer for his future role. There's no better way of expanding his knowledge and interest than by equipping him with modern tools of industry," according to V. W. Fries, vice president in charge of production, White Motor Co. In presenting Carnegie Tech with a heavy duty White engine of the "Mustang" series for future laboratory training of students, Mr. Fries also added that "industry has a bit of enlightened selfishness in so doing." He estimated that by 1971 there will be twice the number of engineering students in all technical colleges and universities as there are today, and the better informed this engineering talent is, the better it will be able to serve industry.

Tuning Fork Tests Master Rods

Compressive forces as high as 45,000 pounds, applied at a rate of 81 cycles per second are developed by a testing machine which is essentially a giant tuning fork. Used in simulated service fatigue testing of an aircraft engine master connecting rod, the machine loads the specimen in the same manner as it would be loaded in actual service and completes one-million compression cycles in only 3½ hours.

Tines of the tuning fork, developed by Weber Instrument Corp., are 12 inch H-beams, 8 feet long, boxed in with ½-inch plate for added mass and rigidity. Beams are fastened at the top to a 1-inch steel plate, and the fork thus formed is suspended by cables from an A-frame. An electromagnetic vibration exciter is coupled to one of the tines near the bottom. Flexible mechanical fuses in the coupling protect the exciter from excessive bending moments. The master rod is mounted between the tines of the fork, approximately 44 inches from the top.

A device for preloading the master rod in compression is part of the test set-up. Preloading is necessary to insure that all forces applied to the master rod will be in the compression direction as they would be in the engine during operation. Six tie rods bridge the tines and load them through compression springs. Strain gages cemented to the rods permit equal loading. Strain gages mounted on a link connecting rod indicate master rod loading through an amplifier and oscilloscope. Failure of the specimen is indicated by a change in the oscilloscope indication.

Because of the nature of the vibrating system, little power is

METROPOLITAN is a new small car introduced in March by Nash Motors. Designed by Nash, the car is made in England by British Motors Corp. and uses the English Austin A-40, 4-cylinder, overhead-valve engine developing 42 horsepower. Known as the NKI and NXI during its development, the car is made in convertible and hardtop models with 85-inch wheelbase and overall height of 54½ inches. Tests have shown that gasoline mileage of 40 miles per gallon is attainable with this two or three passenger automobile

Specify

GITS *Unit** SEAL

Result:

Economy

"Economy . . . counts not in savings but in selection."—*Edmund Burke*

Economy through Efficiency

Gits Unit Seal proves itself in dependable performance over a wide range of operating conditions—including extra-high speed, heat and pressure applications. Operation at peak efficiency always means dollars-and-cents savings.

Economy through Adaptability and Versatility

Gits Unit Seal fits many applications as a standardized item actually carried in stock. You harness the savings of mass production to your own specific needs. Gits Unit Seal already has wide application in the following fields: Washing Machines, Disposal Units, Gear Motors, Speed Reducers, Aircraft Turbine Pumps, Accessory Drive Units, Jet Propulsion Units, Electrical Power Equipment, Automotive Accessories, Business Machines, Standard and Special Machine Tools.

Economy through Long Life

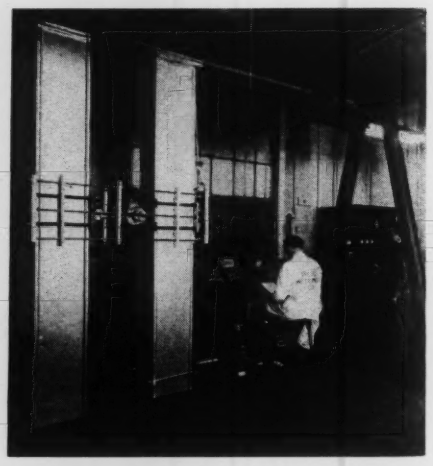
Gits Unit Seal is designed for maximum life in any recommended application. Here's the real "proof of the pudding" in saving money.

Write Today For FREE Illustrated Brochure, or send us your seal problem. Our experienced engineering staff is at your service.

*Cartridge Seal . . . requiring only 25% more space than lip-type seals.

GITS BROS. MFG. CO.

1868 S. Kilbourn Avenue Chicago 23, Illinois



Giant tuning fork rapidly completes simulated service fatigue tests, requires little operating power and can apply high loads

required. Only hysteresis or heating losses in the system must be made up by the vibration exciter. Proper vertical positioning of the master rod is used to change the natural frequency of the system so that required loads and convenient failure times are obtained.

Refrigerator Unit Insulated in Seconds

Insulating panels of Styrofoam (expanded polystyrene) are molded around refrigerator evaporator coils in 30 seconds by a new press developed by the Norge Division of Borg-Warner. Using a pressure of 80,000 psi, a quadruple action air-operated press applies the insulation on four sides at one time. A second operation presses on the back panel.

Cost savings are said to be considerable compared to the conventional method of glass fiber insulation where the glass fiber is enclosed in a plastic bag and secured with a metal shell. Insulation by this method may contain voids, but insulation with Styrofoam is voidless and waterproof.

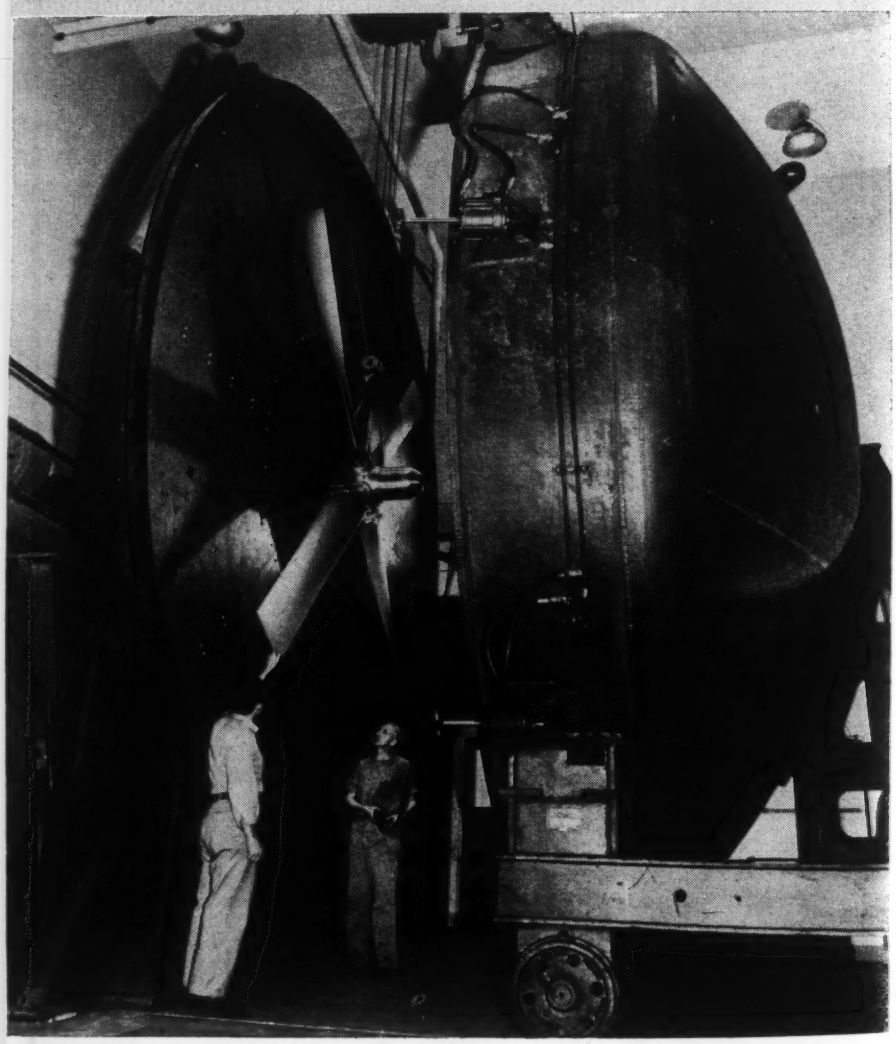
Third annual award competition for the best 1954 paper on corrosion has been announced by the NACE. Further information and a copy of the association's "Guide for the Preparation and Presentation of Papers" may be obtained from A. B. Campbell, Executive Secretary, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

Integral HP Motors To Latest NEMA Standards

In line with recent trends in the electric motor industry, smaller, quieter induction motors in integral horsepower ratings conforming to the latest NEMA standards are now being produced by Westinghouse Electric Corp. In addition to providing more power in a smaller package, the motors have improved insulation, more efficient and better protected bearings, improved ventilation, and improved dripproof enclosures.

New synthetic resin insulation used on rotor and stator windings is said to have life more than three times greater than previously used insulation because of higher thermal endurance. Dielectric strength, corrosion resistance, vibration resistance, and resistance to physical damage of the new insulation, labeled Bondar, are also superior to earlier insulation. Slot insulation, stator dip insulation

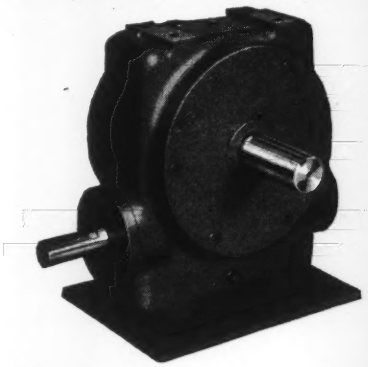
GIANT CLAM SHELL provides near perfect vacuum for precise measurement of propeller dynamic unbalance at actual flight blade angles in the recently completed experimental test building of the Hamilton Standard Div., United Aircraft Corp.



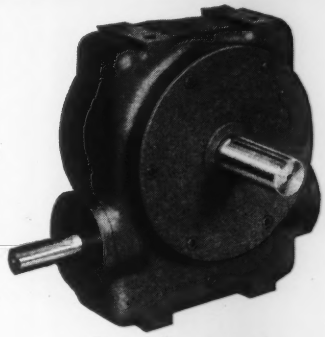
D.O.James

TYPE "S" WORM GEAR SPEED REDUCERS

RATIOS FROM 5.66:1 TO 100:1 — .04 HP TO 15.6 HP

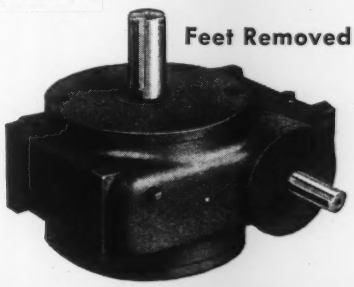


Horizontal Type—Worm at Bottom
Sizes 17S, 22S, 26S, 33S

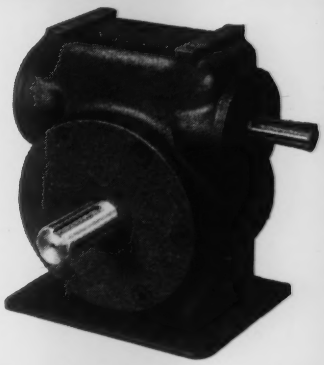


Base Removed

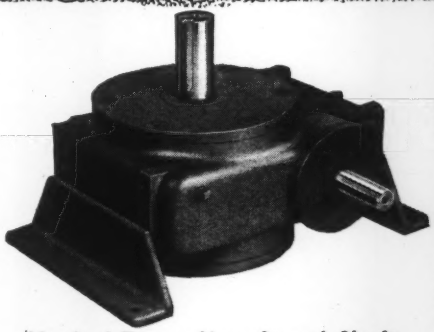
Sizes 17 to 33 inclusive have detachable bases or feet, are adaptable to horizontal or vertical applications, convertible from one to the other, or may be used without bases to suit particular installations.



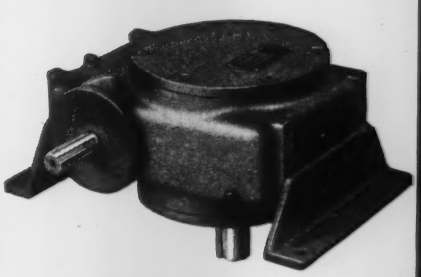
Feet Removed



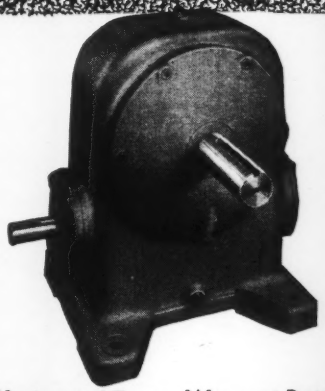
Horizontal Type—Worm at Top
Sizes 17ST, 22ST, 26ST, 33ST



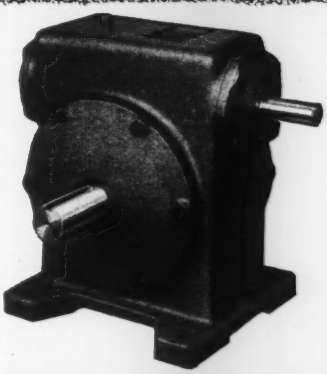
Vertical Type—Slow Speed Shaft Extends Upward
Sizes 17SV, 22SV, 26SV, 33SV



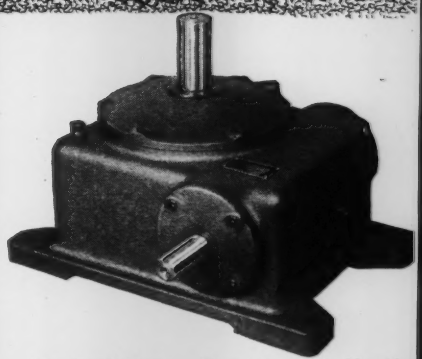
Vertical Type—Slow Speed Shaft Extends Downward
Sizes 17SV, 22SV, 26SV, 33SV



Horizontal Type—Worm at Bottom
Sizes 38S, 42S, 46S, 54S



Horizontal Type—Worm at Top
Sizes 38ST, 42ST, 46ST, 54ST

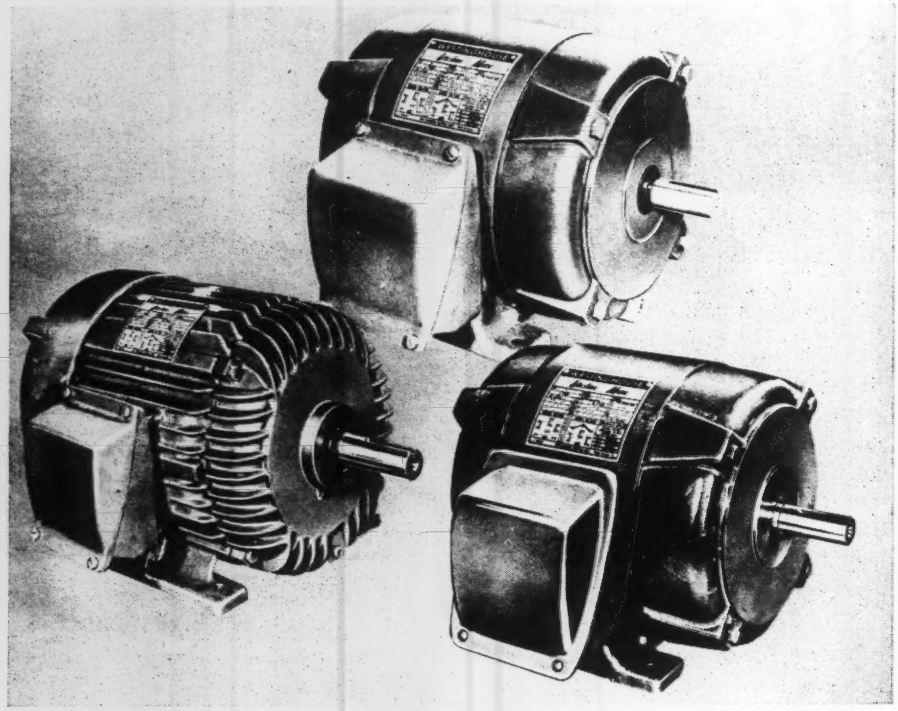


Vertical Type—Slow Speed Shaft Extends Downward or Upward
Sizes 38SV, 42SV, 46SV, 54SV

D.O.JAMES GEAR MANUFACTURING CO.

Since 1888 — Power Saving Equipment for Industry

1140 W. MONROE STREET CHICAGO, ILLINOIS



Lighter, smaller and quieter electric motors in integral horsepower ratings conform to latest NEMA standards

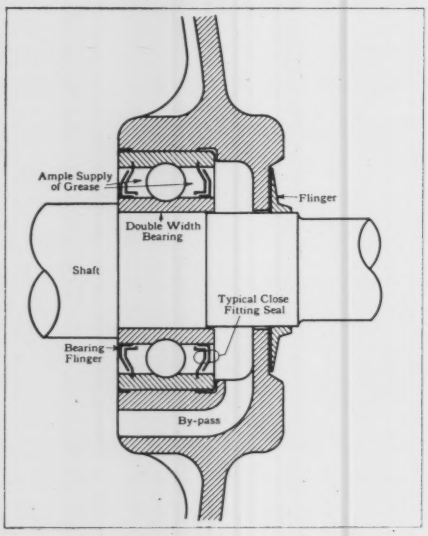
and motor lead insulation have been similarly improved.

Dripproof motor enclosures have the ventilation openings, which are comparatively small, located normal to the shaft axis in one quadrant of the end brackets. Rotation of the end brackets to the proper position provides completely dripproof protection for the motor, even when wall or ceiling mounted. This design has been found to be virtually splashproof and as a consequence, separate splashproof models have been eliminated from the Life-Line A series of motors.

Improved bearing sealing and lubrication have also been incorporated into the new motors. Four-way seals are used—two seals on each side of the bearing. Inner seals are attached to outer bearing races and are stationary while outer seals rotate with inner bearing races. Outer seals or flingers, throw off any foreign matter which might enter the bearing. A bypass equalizes air pressure on both sides of the bearings of enclosed motors and prevents "breathing" and the accompanying lubricant contamination. An external flinger prevents entry of foreign matter into the bypass. Grease used in the bearings was developed in conjunction with suppliers and possesses properties such as oxidation resistance and high melting point which assure long life.

Noise reduction from 55-60 decibels to 50-55 decibels has been achieved by careful electrical and mechanical design. Noise level of the new motors is comparable to that in a typical office. Two of these motors produce no more sound than one of the previous models.

Integral bearing seals, an external flinger and a bypass to equalize air pressure on both sides of bearings in Life-Line A motors greatly reduce the probability of lubricant contamination

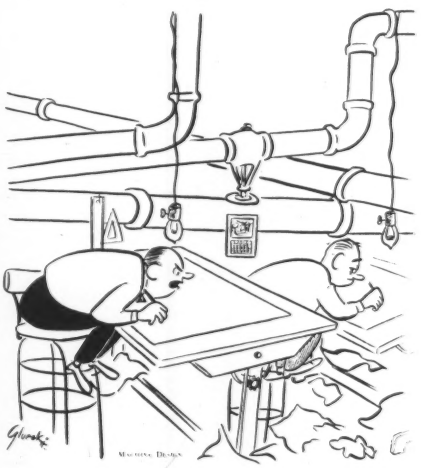


Precision Rubber Bonding to Nylon

Rubber may be bonded to nylon by a new method of chemical bonding developed by Minnesota Rubber and Gasket Co. Resulting in more economical manufacturing and assembly than the previous method of mechanical fastening, the bonding method allows the bearing qualities of nylon to be combined with close tolerances obtainable with rubber molding. The chemical bond is said to outlast the life of the individual parts.

Among some of the recent applications are drive wheels for record players, pump impellers, cam wheels, and idler wheels. Most of the installations have been for small control devices.

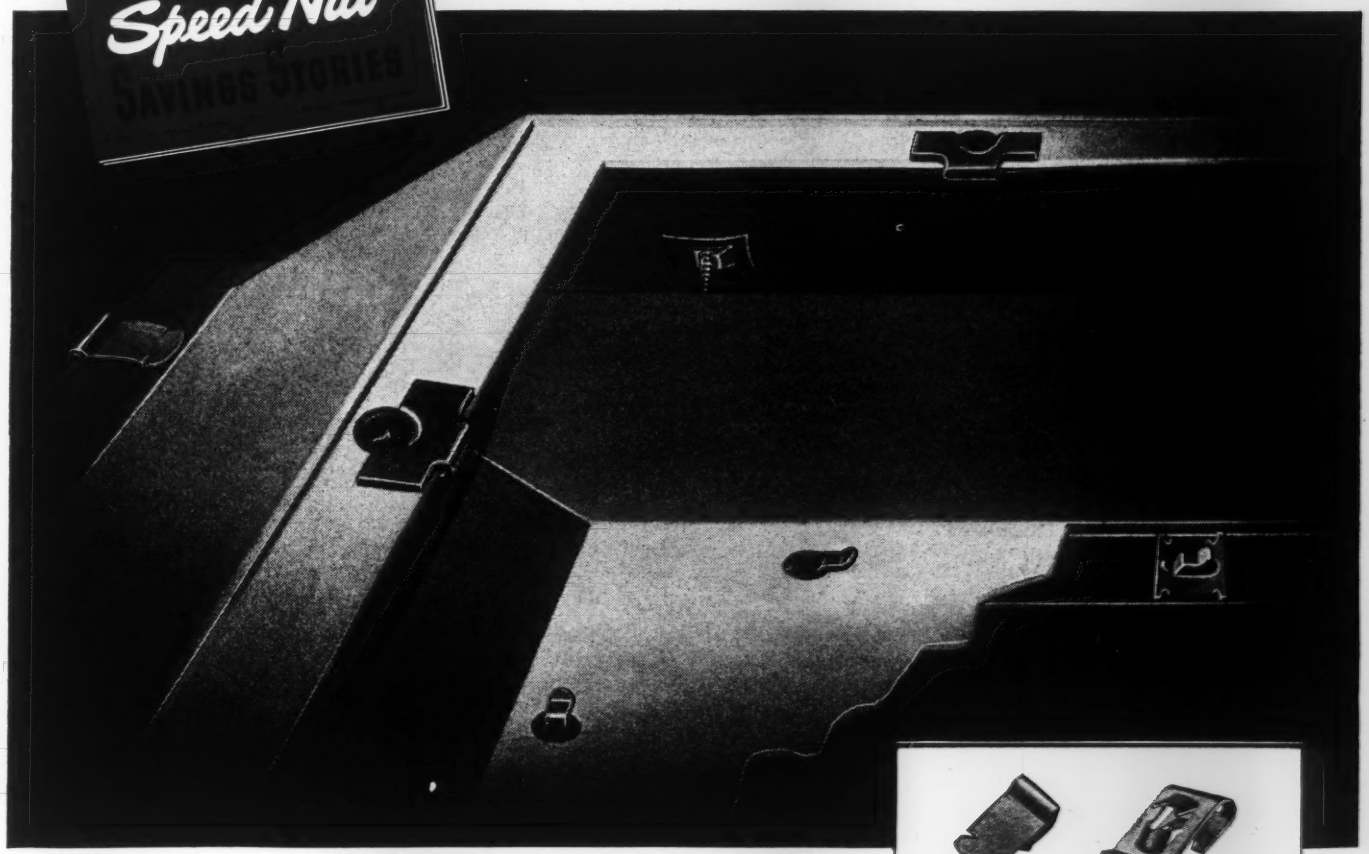
Du Pont has scheduled a $3-million laboratory for completion in early 1955. The laboratory will have the most modern equipment

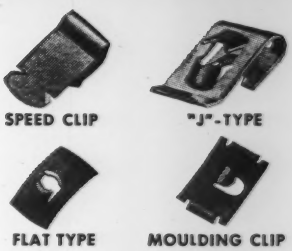


"I get the impression we're considered a necessary evil around here."

FASTEST THING IN FASTENINGS®

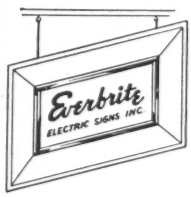
Speed Nut SAVINGS STORIES





These four SPEED NUTS perform important time-saving functions in the assembly of the Everbrite sign shown in cutaway illustration above. Made of highest quality spring steel, SPEED NUT fasteners are lightweight, self-retaining and vibration-proof.

Plastic Sign Maker "Signs Up" 48% SPEED NUT® Savings!



Everbrite Electric Signs, Inc., Milwaukee, Wisconsin, has found the "sign of savings" in Tinnerman SPEED NUT brand fasteners. Designers at Everbrite specified 4 different types of SPEED NUTS in the production of these smart plastic signs. The result was an estimated savings of 48% in assembly time, cost of materials, and materials handling!

SPEED NUT applications in plastics present unlimited money-saving opportunities. Production advantages like these are the reasons . . . SPEED NUTS eliminate costly threaded inserts, are self-retaining and vibration-proof, make faster, easier "blind" attachments, permit greater design flexibility, harness cold-flow tendencies, eliminate heat sealing, and minimize assembly damage!

For cost-saving details on the use of SPEED NUTS in plastics, call in your Tinnerman representative.

Send for your "SAVINGS STORIES" booklet of interesting SPEED NUT savings to industry. Write today:

TINNERMAN PRODUCTS, INC., Dept. 12, Box 6688, Cleveland 1, Ohio. *In Canada:* Dominion Fasteners Ltd., Hamilton, Ontario. *In Great Britain:* Simmonds Aerocessories, Ltd., Treforest, Wales. *In France:* Aerocessoires Simmonds, S. A. – 7 rue Henri Barbusse, Levallois (Seine).

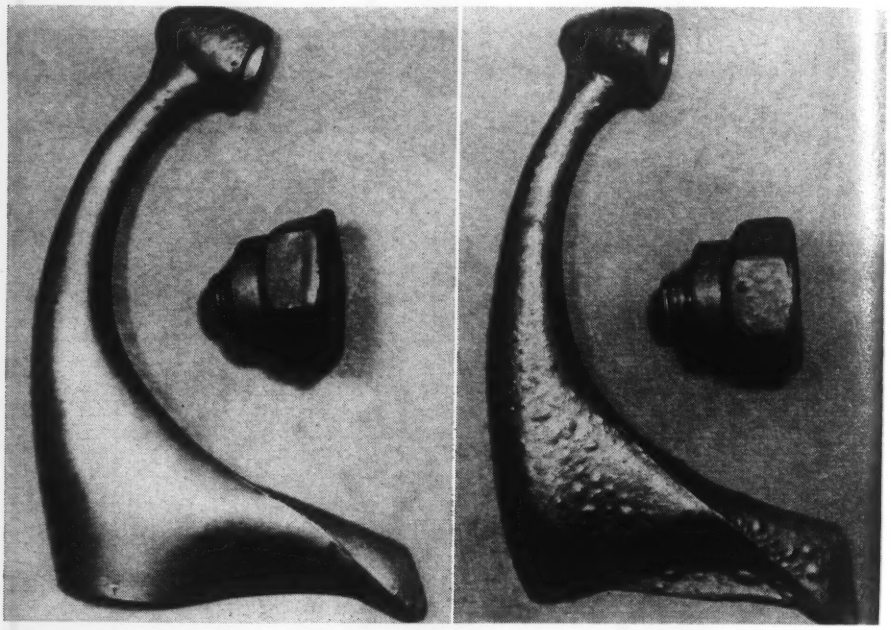
TINNERMAN Speed Nuts®

MORE THAN 8000 SHAPES AND SIZES

available for developing technical data on the use and processing of the polychemicals department products. Facilities for engineering services in the plastics field will be several times those of the present laboratory in Arlington, N. J., which the new laboratory will replace.

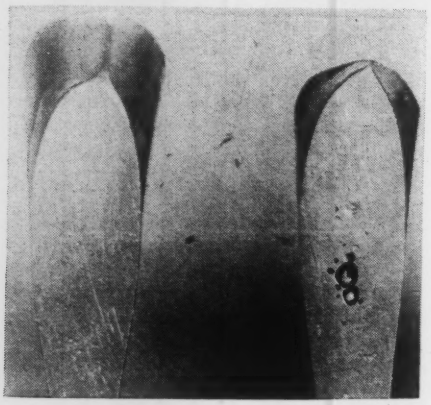
Vacuum Die Casting An Improved Method

A new vacuum die casting method and equipment, for use with zinc alloys, greatly reduces internal porosity, increases thickness and hardness of the casting skin, and increases tensile strength. Developed by the Nelmor Corp., the method seals a standard die for relatively high evacuation before injection of the molten metal. Production use has proven practicality of the method.



After heating at 750 F for 45 minutes condition of surfaces of vacuum die castings, left, and conventional die castings, right, show results of gas being brought to the surface. Though gas was brought to the surface of vacuum casting, the amount was not as great because of the higher density obtained with the vacuum process

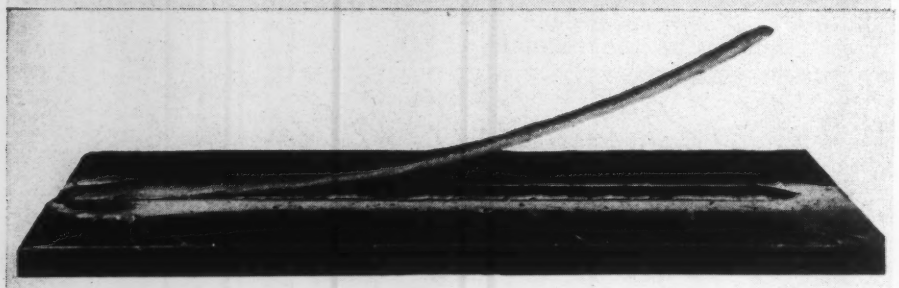
Sectioned vacuum die casting, left, and conventional die casting, right, show absence of large sub-surface pores in vacuum casting



A standard die casting machine operated by special semiautomatic electric controls is used in the process. Any casting die normally accommodated by the machine can be used. Though some die modification is necessary, the die may still be used for conventional die casting after modification.

A somewhat longer cycle than the conventional practice is required when using the vacuum method; however, developers of the process say that, as a rule-of-thumb estimate, the method is economically sound for any part having a rejection or scrappage rate of 10 per cent or more, because of the reduced rejection rate obtainable. Typical of die castings which should benefit through use of the process are chrome-plated parts; castings subjected to heating during processing or use; parts where machining would expose porosity; castings with definite strength requirements; pressure-tight castings; and in general, parts having deep draws with insufficient casting pressure, or where cold-shut is practically impossible to avoid.

NEARLY SELF-CLEANING WELDS can be made with new electrodes containing large quantities of powder metal in their coatings. This Lincoln Electric Co. photo shows slag lifting from a bead as the weld cools. Higher welding speeds; smoother and more uniform welds, and less spatter, undercutting and gouging are other advantages claimed for the new Lincoln electrodes, first introduced in October, 1953



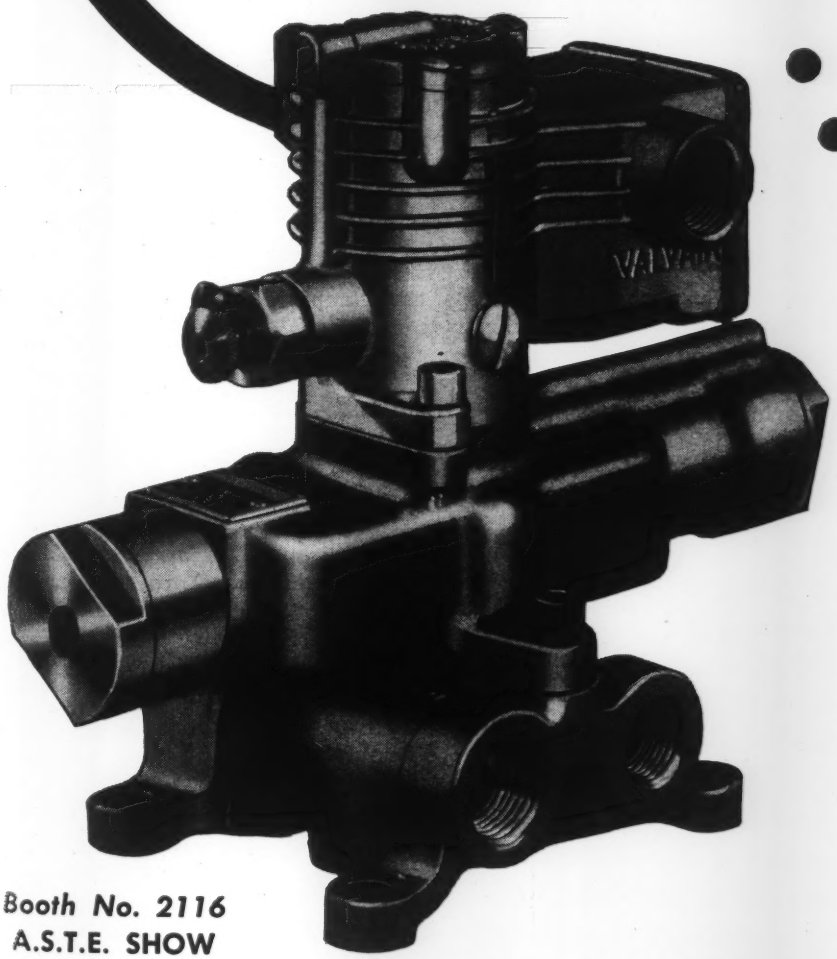
New president of the Engineers Joint Council is Dr. Thorndike Saville, dean, College of Engineering, New York University. Elected vice president was Carlton S.

SPEED KING

SOLENOID PILOT OPERATED CONTROL VALVE

by VALVAIR

DESIGNED AND BUILT TO J. I. C. STANDARDS



- **A Hefty Assist to Automation**
- **Fully Enclosed**
- **Integral Junction Box**

The Valvair line broadens again — with Speed King's exclusive features. All parts are totally enclosed. The Speed King will operate submerged in water or buried in sand. Simplicity! — only two moving parts. Molded coil — no wear or shorting out. 20,000,000-cycle life and more. Speed King is industry's most rugged and compact valve.

Other features: for pressures from 35 to 200 p.s.i. pneumatics, hydraulics, vacuum; complete line—2-way, 3-way, 4-way and 4-way-5-port (2-pressure) models; foot or sub-base (manifold) mounting; pipe sizes —¼", ⅜", ½", ¾", and 1".

Ask for Bulletin "D-4".

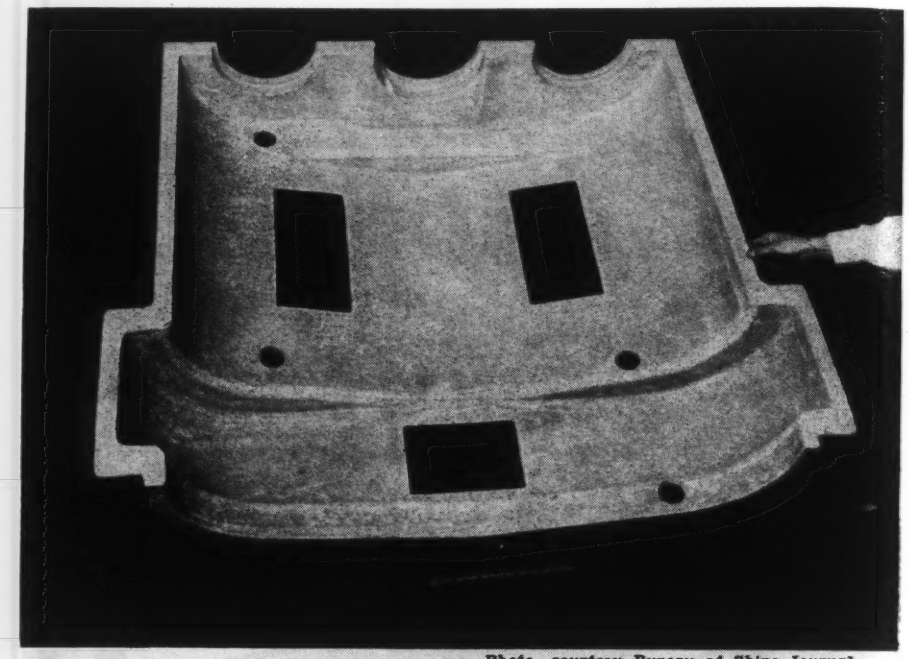
Booth No. 2116
A.S.T.E. SHOW

Representation in: BALTIMORE • BIRMINGHAM • BOSTON
BROOKLYN • BUFFALO • CHARLESTON, W. VA. • CHICAGO
CLEVELAND • CRANFORD, N. J. • DAYTON • DENVER
DETROIT • EUREKA, CALIF. • GLENSIDE, PA. • HOUSTON
KANSAS CITY, MO. • LOGANSPORT, IND. • LOUISVILLE
MILWAUKEE • MINNEAPOLIS • PASADENA • PITTSBURGH
PORTLAND • ST. LOUIS • SAVANNAH • SEATTLE
MONTREAL • TORONTO • VANCOUVER

VALVAIR CORPORATION *Affiliate: Sinclair-Collins Valve Company*
953 BEARDSLEY AVE., AKRON 11, OHIO

Rely Upon Valvair DIVERSATILITY

Proctor, president, Moran, Proctor, Mueser and Rutledge, and formerly, president of ASCE.



Photo, courtesy Bureau of Ships Journal

GEAR CASE COVER of laminated plastics. Nonductile characteristics of this material are advantageous in light parts which must take abuse without deformation

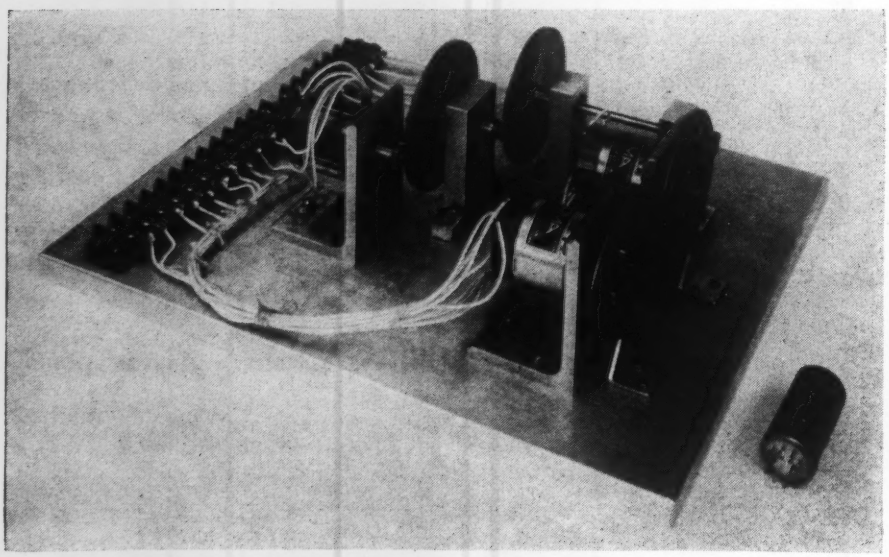
Miniaturized Computer Unit Uses Heat Transfer

Capable of performing operations five times as fast as the swiftest previously made comparable equipment, a new miniature analog computer component utilizes heat transfer as the basis of its operation. Manufactured by the ARMA Corp., the new component uses a transducer in which an incoming electrical signal is dissipated into heat. Temperature differential created by this incoming electrical signal is then communicated to a pair of temperature-sensitive conductors mounted in a Wheatstone bridge. Heat thus produced causes an unbalance in the Wheatstone bridge circuit and the amount of this unbalance is detected by means of a reference signal applied to the bridge.

To overcome time lag inherent in thermal systems, the sensing elements are designed with heaters operated at very high temperatures, making the time constants of the order of a few milliseconds. This fast-acting thermal transducer has the advantage of being able to use ac signals for differentiation and integration rather than being restricted to dc signals.

No moving parts are used in the unit, and it is said to be mass producible. Applications of this lightweight component will be in the computer, servo, and instrument fields.

Small thermal type analog computer unit, right, about as large as a pack of cigarettes, replaces the geared analog computer assembly shown at the left and is about one-fifth the weight



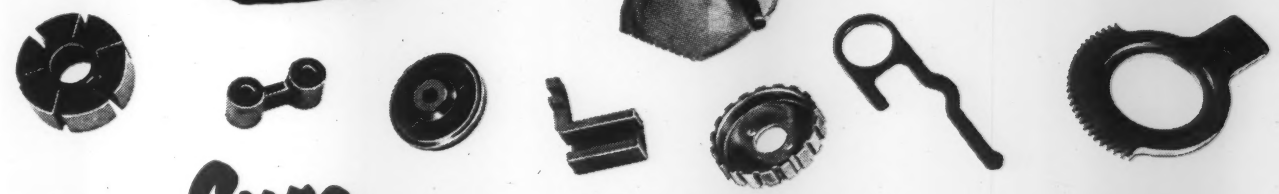
Aluminum Alloy Approved For Pressure Vessel Use

Aluminum alloy GR40A, was recently approved by the Boiler Code Committee of the American Society of Mechanical Engineers for construction of unfired pressure vessels in accordance with the rules of Section VIII of the 1952 ASME Boiler and Pressure Vessel Code. Approval of this alloy became effective with the publishing of ASME Case 1174.

Alloy GR40A, designated commercially by Alcoa as A54S, is said to offer higher mechanical properties than any of the aluminum alloys previously approved for welded pressure vessels. For this reason, allowable design stresses are higher. For elevated temperature operation, the alloy is desirable because it maintains its strength better at higher temperatures.

Although GR40A can be welded

YOU SAVE WHEN YOU USE OILITE FINISHED MACHINE PARTS



Sure... these intricate parts can be machined out of solid metal. *That's the expensive way.*

But... these FINISHED MACHINE PARTS are being made by OILITE *at a Fraction of the Cost.*

Oilite Finished Machine Parts serve the same purpose as conventional "machined" parts. Their performance is just as good, often better, because they can be self-lubricating and made to closer precision tolerances.

Recent achievements by Oilite Research have materially broadened the scope and application of Oilite — Products of Metal Powders.

AMPLEX
DIVISION OF CHRYSLER CORPORATION
Detroit 31, Michigan, Dept. D

6761

Call an Oilite Engineer. Let him develop your ideas. He will suggest ways and means for decreasing your part costs and show you how to attain other important goals.

FIELD ENGINEERS, DEPOTS AND DEALERS THROUGHOUT UNITED STATES AND CANADA

Oilite Products of Metal Powders Include:
BEARINGS, FINISHED MACHINE PARTS, CORED AND SOLID BARS, PERMANENT FILTERS AND SPECIAL UNITS

by all conventional methods, the semiautomatic inert-gas metal-arc process and the inert-gas metal-arc process (tungsten-arc) are preferred.

Atomic Cement Is New Radiation Source

Cement mixed with radioactive fission products and formed into a cylindrical concrete block is a new source of radiation developed at the Argonne National Laboratory. Utilizing radioactive waste, the radioactive cement-fission product mixture is surrounded on all sides, top, and bottom by both a several-inch layer of ordinary cement and a several-inch layer of lead. Materials to be irradiated may be lowered through an opening into the active region of the source.

The source, equivalent to several pounds of radium is inexpensive since it uses a byproduct of reactor operations. In addition it provides an ideal method of disposing of radioactive waste. The first experimental source has been shipped to MIT's Dept. of Food Technology for studies on the effects of radiation on the micro-organisms in food.

Tantalum strip, precision-rolled to very close tolerances and to thin gages and foils, for use throughout industry, is now available from the Industrial Div. of American Silver Co. Inc. Custom rolled in strip up to 6 in. wide as thin as 0.0005 in., to tolerances as close as ± 0.0001 in., the strip is available in any quantity.

Meetings and Expositions

Apr. 14-16—

Society for Experimental Stress Analysis. Spring meeting to be held at the Hotel Netherland Plaza, Cincinnati, O. W. M. Murray, P. O. Box 168, Cambridge 39, Mass., is secretary.

Apr. 18-23—

American Ceramic Society Inc. Fifty-sixth annual meeting to be held at the Palmer House, Chicago, Ill. Charles S. Pearce, 2525 North High St., Columbus 2, O., is secretary.

Apr. 20-21—

American Zinc Institute Inc. Thirty-sixth annual meeting to be held at the Hotel Statler, St. Louis, Mo. Ernest V. Gent, 60 East 42nd St., New York 17, N. Y., is secretary.

Apr. 26-28—

American Management Association. Manufacturing conference to be held at the Hotel Statler, Cleveland, O. Additional information may be obtained from society headquarters, 330 West 42nd St., New York 36, N. Y.

Apr. 26-28—

Metal Powder Association. Annual meeting and exhibit to be held at the Drake Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 420 Lexington Ave., New York 17, N. Y.

Apr. 26-30—

American Society of Tool Engineers. Convention and industrial exposition to be held at Bellevue-Stratford Hotel, Convention Hall and Commercial Museum, Philadelphia, Pa. H. E. Conrad, 10700 Puritan Ave., Detroit 21, Mich., is executive secretary.

May 4-8—

American Welding Society. National spring technical meeting and welding and allied industry exposition to be held at Hotel Statler and Memorial Auditorium, Buffalo, N. Y. J. G. Magrath, 33 West 39th St., New York 18, N. Y., is secretary.

May 8-14—

American Foundrymen's Society. Annual convention and biennial exposition to be held at Public Auditorium, Cleveland, O. W. W. Maloney, 616 S. Michigan Ave., Chicago 5, Ill., is secretary-treasurer.

May 17-20—

Basic Materials Exposition. Second exposition and conference to be held at the International Amphitheatre, Chicago, Ill. Additional information may be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

May 26-27—

American Iron & Steel Institute. Annual meeting to be held at the Waldorf-Astoria Hotel, New York, N. Y. Additional information may be obtained from society headquarters, 350 Fifth Ave., New York, N. Y.

June 6-9—

American Gear Manufacturers Association. Annual meeting to be held at the Homestead Hotel, Hot Springs, Va. J. C. Sears, One Thomas Circle, Washington 5, D. C., is executive secretary.

June 7-10—

Society of the Plastics Industry. National Plastics Exposition to be held at the Public Auditorium, Cleveland, O. William T. Cruse, 67 West 44th St., New York 36 N. Y., is executive vice president.

How do you buy Socket Screws?

Do you specify some one make by *habit*, because you think *all* such fasteners are alike — all simply "screws with hex sockets?" If you do, and have never used P-K Socket Screws, break the habit *once* and give them a trial. You'll find that the hex shaped socket is about the *only* way other makes and P-K are "alike."

Look Beyond the Hex

It pays to look beyond the socket when you buy Socket Screws. Compare every detail of product and service, and you'll find P-K Socket Screws take top honors in every test for quality, performance, economy.

Why miss out on any of the advantages you can get with P-K Socket Screws? Try them. For samples, catalog, or any needed information, see your P-K Distributor, or write: Parker-Kalon Division, General American Transportation Corporation, 200 Varick St., New York 14.

The Only SIZE-MARKED Socket Cap Screws — with Gear Grip. Prevents errors . . . saves time and wasted screws when sizes get mixed up. Helps maintenance and service men in re-assembly. *Maximum Strength* — head, socket, threads accurately formed by P-K's cold-pressure process. Steel structure "flows" to conform to all contours, assures maximum strength at points of greatest stress.

FOR ADVANCED DESIGN that speeds assemblies — makes them simpler, stronger — and saves errors.

FOR TOP QUALITY and tolerance gaged to your most exacting specifications — and guaranteed.

FOR ASSEMBLY STRENGTH okayed in a million punishing tests by thousands of satisfied users.

FOR PLANNING AIDS and buying data patterned to your special needs, plus advice on assembly.

FOR SUPPLY SERVICE set up for fast action and lower purchasing expense — by local Distributors.

GET **ALL** THESE ESSENTIALS OF COST-WISE ASSEMBLY

PARKER-KALON SOCKET SCREWS

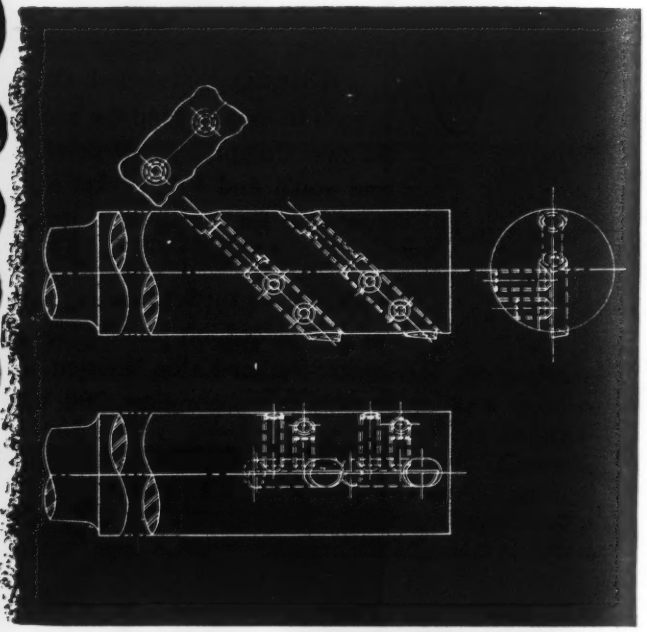
SAY **P-K**

FULL RANGE of styles and sizes. You'll find any Socket Screw you need in P-K's complete line. Hex Keys in all sizes, and several handy sets.

In Stock for immediate delivery — see your nearby P-K Distributor

SPECIFY HOLO-KROME . . . the BETTER fastening method.

SET SCREWS



HK SOCKET SCREWS ARE:

- Held to Class 3 Thread Fit . . . Individually hand inspected.
- GUARANTEED TO GIVE UNFAILING PERFORMANCE.

HK SOCKET SCREWS ARE:

- Made of special analysis alloy steel by a Holo-Krome patented process and heat treated to develop the utmost in physical properties.
- Quality controlled in Holo-Krome's own Physical and Chemical laboratories.

CALL YOUR H-K AUTHORIZED INDUSTRIAL DISTRIBUTOR *TODAY*

D8

HOLO-KROME

Completely Cold Forged

SOCKET SCREWS

THE HOLO-KROME SCREW CORP., HARTFORD 10, CONN. U. S. A.

HELPFUL LITERATURE

FOR DESIGN EXECUTIVES

1. Miniature Hydraulic Valve

Skinner Chuck Co., Skinner Electric Valve Div.—Having a capacity up to 5.4 gpm, V10 series miniature hydraulic valve described in 2-page bulletin 529, is a solenoid operated two or three-way unit for automatic control of hydraulic systems up to 1000 psi. Complete specifications are provided.

2. Rivets & Screws

Cuyahoga Rivet & Screw Co.—Solid rivets; machine, tapping and drive screws; nuts; and stove bolts made from steel, aluminum, copper, brass, Monel and stainless steel are listed with dimensional and price data in 36-page pocket-size catalog. Of special interest are several 60, 78 and 100-degree countersunk head types not usually listed.

3. Electromagnetic Controls

Automatic Switch Co.—Services and products of this company for use on the power side of electronics systems are described in 38-page brochure "When Normal Power Fails . . ." It discusses such controls as automatic transfer switches, engine-generator starting units, differential relays, time delay relays and control panels. Many other related data are given.

4. Flow Control Valves

A-P Controls Corp.—Such flow control problems as stop or start, mix or blend, meter or measure and control of pressure differential, pressure, temperature and flow can be solved with line of flow control valves described and illustrated in 4-page bulletin. They can be used with liquids, gas and air, gas and refrigerants. Variety of types are covered.

5. Hydraulic Controls

Pantex Mfg. Corp., Hydraulic Div.—Three available bulletins on industrial hydraulic controls include 4-page bulletin AD on cartridge type relief valves of 350-5000 psi; 6-page bulletin 25 on solenoid controlled ¼-in. directly operated four-way valves of 100-5000 psi; and 6-page bulletin 55 on solenoid controlled ⅜-in. pilot operated four-way units.

6. Cam Follower Rollers

Smith Bearing Co.—Detailed description of the new high capacity stud cam follower with load and life ratings and specs for both H C S cam follower and the regular type comprises information provided in 6-page folder 217. Units are used where high speeds and heavy load carrying capacity are essential.

7. Electronic Components

Stackpole Carbon Co., Electronic components Div.—56-page catalog RC-9 offers wealth of helpful information on line of fixed and variable composition resistors, line and slide switches, fixed composition capacitors, powdered iron cores, molded coil forms and Ceramag ferromagnetic cores. Electrical and mechanical specifications, dimensions and application data are covered.

8. Industrial Pumps

Tuthill Pump Co.—Catalog 101, one of two 12-page brochures available, covers line of model L series of small industrial pumps designed for lubricating hydraulic, transfer, circulating and burning oils service. Catalog 102 features model C series of general purpose pumps for use with noncorrosive liquids with lubricating qualities. Pump guide at front of each presents services, operating data and distinguishing features for each model.

9. Torque & Special Motors

B. A. Wesche Electric Co.—Examples of torque and special motors and custom built collector ring assemblies are pictured in 8-page bulletin. Units are used where direct application of measured power is required. Collector rings are used in electrically heated rolls, revolving platforms or cranes and rotating parts on machinery.

10. Alloy & Stainless Balls

Coolidge Corp.—Size, sphericity and shipping data are tabulated on chrome alloy and stainless steel balls, along with ordering, packaging and shipping information, in 4-page folder. Grade and hardness data are included.

11. Universal Joints

Gear Grinding Machine Co., Joint Div.—"The Universal Favorite" is title of new periodical containing news and features on universal joints. It will cover case histories from industry, application information, engineering suggestions and present features on universal joint problems.

12. Casting Material Selector

Lebanon Steel Foundry—Reference data on 19 carbon and low alloy grades and 17 stainless and corrosion-resistant grades of steel casting materials are given in Circle L slide chart. When guide arrow is adjusted to proper grade, windows in chart reveal nominal analyses, minimum mechanical properties and heat treatment. ACI, AISI, ASTM, Hydraulic Institute, SAE, U.S., Military and Federal designations are given as well.

13. Stainless Alloy Products

Solar Aircraft Co.—Including bellows-type expansion joints ranging from thimble size to 28 ft in diameter, ceramic coated metals for high temperature and corrosion-resistant service, shell mold castings of stainless alloys and custom designed stainless steel items, stainless alloy and other products with applications in process and other industries are considered in 12-page illustrated bulletin PR-353. Gas turbine power plants and turbine engines are also described.

14. Alternating Current Motors

Brook Motor Corp. — Selection guide for standard and special single and polyphase alternating current motors is found in 6-page folder 1253. Various mountings, enclosures, bearings, insulations, shafts, auxiliaries and accessories are offered in wide horsepower range of constant, multispeed and reversible motors. Distinguishing features are described.

USE THE POSTAGE FREE CARDS BELOW for copies of anything listed on this or following helpful literature pages—or for further information on any items in the new parts section or the engineering department equipment section which you'll find on the next several pages.

For additional information on anything advertised in this issue, use the yellow cards in the front section of this magazine.

FIRST CLASS
PERMIT No. 36
(Sec. 34.9 P.L.&R.)
Cleveland, Ohio

BUSINESS REPLY CARD
No Postage Stamp Necessary if Mailed in the United States

4c POSTAGE WILL BE PAID BY—

MACHINE DESIGN
Penton Building
CLEVELAND 13, OHIO

Readers' Service Dept.

1	23	45	67	89	111	133
2	24	46	68	90	112	134
3	25	47	69	91	113	135
4	26	48	70	92	114	136
5	27	49	71	93	115	137
6	28	50	72	94	116	138
7	29	51	73	95	117	139
8	30	52	74	96	118	140
9	31	53	75	97	119	141
10	32	54	76	98	120	142
11	33	55	77	99	121	143
12	34	56	78	100	122	144
13	35	57	79	101	123	145
14	36	58	80	102	124	146
15	37	59	81	103	125	147
16	38	60	82	104	126	148
17	39	61	83	105	127	149
18	40	62	84	106	128	150
19	41	63	85	107	129	151
20	42	64	86	108	130	152
21	43	65	87	109	131	153
22	44	66	88	110	132	154

MACHINE DESIGN 4-54
Penton Building
Cleveland 13, Ohio

Please send literature or detailed information on subjects circled at left to—

NAME TITLE

COMPANY

MACHINES MANUFACTURED

ADDRESS

CITY AND STATE

This Card MUST be completely filled out. Please TYPE or PRINT

15. Industrial Relays

Henschel Corp., Relay Div.—Built from precision-made parts "stacked" to certain standard contact arrangements, line of industrial relays is offered to fit most requirements. Units are described and illustrated in 4-page folder. Various contact arrangements are manufactured.

16. Roller Bushings

Orange Roller Bearing Co.—Standard sizes with dimensions and carrying capacities of roller bushings are listed in 20-page engineering data catalog, 14th edition. Bushings consist of outer race with full complement of rollers assembled integrally. This provides a self-contained unit which is furnished with or without inner races.

17. Machine Mounting Pads

Felters Co., Unisorb Dept.—Questions commonly asked about Unisorb mounting pads for various types of machines are answered in 8-page booklet. Use of the product, elimination of bolts, reduction of transmitted machine vibration and cost are among subjects covered.

18. Dynamometer Systems

General Electric Co.—How G-E direct current dynamometer systems can be used for both motoring and absorption applications is related in illustrated 12-page bulletin GEA-5923. Use can be for testing engines, transmissions, pumps, fans, electric motors, compressors, etc. Extensive technical data on the equipment are included.

19. Data Processing

International Business Machines Corp.—"Light on the Future" is title of 32-page illustrated booklet which discusses the significant principles and components of electronic data processing equipment. In addition to presenting a brief comparison of the construction and application of analog and digital computers, booklet explains functions of input, storage, arithmetic, control and output components.

20. Machinery Mountings

Barry Corp.—Designed to reduce shock and vibration transmission from machinery and also to permit a rapid means of mounting machines without bolting or shims, machine-leveling mounts are covered in 4-page illustrated bulletin DR-154-10. They are described as available in any required load rating. Advantages are pointed up.

21. Air Vibration Equipment

Cleveland Vibrator Co.—16-page illustrated catalog 109 describes line of air vibration equipment, including metallic-impact types and air-cushioned units which operate with a minimum of noise. Photos show use in variety of industries. Line includes 29 mountings and 14 piston diameter sizes.

22. Industrial Engines

Chrysler Corp., Industrial Engine Div.—Specifications for 10 models of 6 and V-8 cylinder industrial engines are found in 20-page illustrated brochure CIE-553. Horsepower charts for each are included. All models are offered in open and enclosed units with or without fluid coupling and torque converter on most models.

23. Air Hose

Quaker Rubber Corp.—Seven different types of air hose for use in different industrial conditions and for working pressures ranging up to 475 psi are illustrated and described in 4-page illustrated bulletin "Quaker Air Hose". Performance data, sizes, weights, recommended uses and construction materials are covered and coupling types are also considered.

24. Screw Machine Products

Delo Screw Products Co.—Facilities and design service for screw machine products manufacture are detailed in 8-page illustrated bulletin 100. It states that primary and secondary operations are designed to customer requirements. Section is devoted to quality control and inspection methods in use by the company.

25. Solenoids

Soreng Products Corp.—Both 110 and 220-v solenoids for constant and intermittent duty with ⅝ to 1⅜-in. strokes are presented in illustrated bulletin. Performance of these TT type units is charted.

26. Custom Glass Parts

Lancaster Lens Co.—Glass parts produced by molding, pressing and blowing, grinding and polishing, sealing, bending, silvering and decorating are described and illustrated in 8-page booklet. Lead, borosilicate, lime and other types of glass are used. Many diverse finished products are shown.

27. Gearmotors

A. O. Smith Corp.—Design features, construction details, specifications and selection data for line of Smithway gearmotors are found in this 12-page brochure. Twenty-one standard speeds ranging from 780 to 13.5 rpm and ratings up to 50 hp are available.

28. Manual Line Voltage Starters

Square D Co.—Details of application, construction, thermal overload relay feature and enclosure for manual line voltage starters of toggle action type are found in 2-page illustrated data sheet. Units are offered in various ratings with lint-tight and general purpose enclosures.

29. Lube Pumps & Reservoirs

Trabon Engineering Corp.—Hydra-Lube pumps for automatic lubrication of hydraulically powered equipment are subject of 4-page illustrated catalog A-1-54. They connect to supply line of any double-acting cylinder. Three, 5 and 12-lb reservoir assemblies for grease or oil, used with the pump, are also covered.

30. Laboratory Instruments

Technology Instruments Corp.—30-page illustrated brochure contains specifications and application data on line of laboratory instruments, precision potentiometers and components. Data are included on slide-wire resistance boxes, angle meters, wide band decade amplifiers, oscillators, phase meters and various types of potentiometers.

31. Hard Facing Welding Rod

Wall-Colmonoy Corp.—Properties, application methods and typical uses of Colmonoy No. 1 hard-facing welding rod are given in 4-page illustrated folder No. 102. Deposited metal resists impact and abrasion.

32. Vertical Turbine Pumps

Worthington Corp.—Illustrated bulletin W-450-B39 deals with features of vertical turbine pumps. These include minimum floor space requirement, separate drive unit, mechanical and hydraulic flexibility and ease of alignment. Applications throughout industry are described.

33. Limit Switch

Square D Co.—Four 4-page bulletins and a dimension sheet comprise available literature on machine tool limit switches. Units feature 11 contact arrangements, along with 80-degree overtravel, oil-tight construction, mounting ease, rugged contact mechanism and simple adjustment.

34. Vibration Testers

All American Tool & Mfg. Co.—"How Much Vibration Will Your Product Stand" is 6-page folder descriptive of eight models of vibration fatigue testing machines. Line includes machines with both vertical and horizontal table movements and table load capacities from 10 lb at 10 g to 100 lb at 10 g. Frequency on all models is 10 to 60 cps, manually, and 10 to 55 cps, automatically.

(Continued on Page 226)

1	23	45	67	89	111	133
2	24	46	68	90	112	134
3	25	47	69	91	113	135
4	26	48	70	92	114	136
5	27	49	71	93	115	137
6	28	50	72	94	116	138
7	29	51	73	95	117	139
8	30	52	74	96	118	140
9	31	53	75	97	119	141
10	32	54	76	98	120	142
11	33	55	77	99	121	143
12	34	56	78	100	122	144
13	35	57	79	101	123	145
14	36	58	80	102	124	146
15	37	59	81	103	125	147
16	38	60	82	104	126	148
17	39	61	83	105	127	149
18	40	62	84	106	128	150
19	41	63	85	107	129	151
20	42	64	86	108	130	152
21	43	65	87	109	131	153
22	44	66	88	110	132	154

MACHINE DESIGN 4-54
Penton Building
Cleveland 13, Ohio

Please send literature or detailed information on subjects circled at left to—

NAME TITLE

COMPANY

MACHINES MANUFACTURED

ADDRESS

CITY AND STATE

This Card MUST be completely filled out. Please TYPE or PRINT

FIRST CLASS
PERMIT No. 36
(Sec. 34.9 P.L.&R.)
Cleveland, Ohio

BUSINESS REPLY CARD
No Postage Stamp Necessary if Mailed in the United States

4c POSTAGE WILL BE PAID BY—

MACHINE DESIGN
Penton Building
CLEVELAND 13, OHIO

Readers' Service Dept.

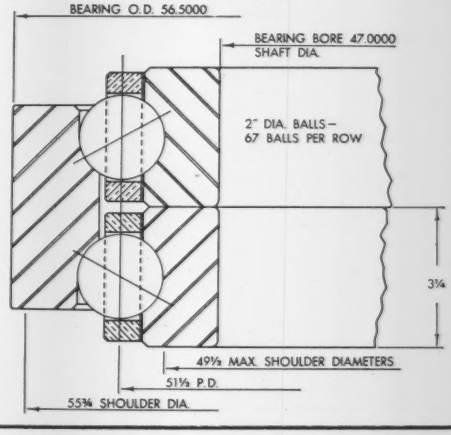
Here are the bearings that "couldn't be built"... *as produced by Kaydon*

THE manufacturer who wanted these bearings had been told they "couldn't be built." Or at least that's what he'd been told *until* he contacted **KAYDON**. What he required was a bearing 56½" in diameter combining high capacity, and exceptional precision for concentricity and face runout that would fit in limited space.

KAYDON designed a double-row angular contact ball bearing (see sketch at right). Actual tests have proved that the bearing fulfills every requirement.

If your designs require special bearings — bearings of exceptional strength, close-tolerance precision and/or very thin section — it will pay you to contact **KAYDON** of Muskegon. **KAYDON** has a long-standing reputation for accomplishing the near impossible.

CROSS SECTION — *The bearing that couldn't be built*



KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust • Roller Radial • Roller Thrust • Bi-Angular Bearings

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

PRECISION BALL AND ROLLER BEARINGS

Helpful Literature

(Continued from Page 224)

35. Electrical Control Centers

Clark Controller Co.—Designed to aid planning, project, layout and other design engineers, 24-page well-illustrated booklet describes advantages of centralized electrical control systems through the use of alternating current motor control centers. Typical installations, specifications, construction details and planning tips are given.

36. Hard-Facing Service

Cleveland Hard Facing Inc.—Applications of hard facing to minimize wear, corrosion and abrasion as well as to provide resistance to high temperatures and impact are detailed in 4-page illustrated bulletin. Facilities and services offered by company are covered.

37. Industrial Filter

Murray-Way Corp.—Continuous automatic operation, self-cleaning design, low operating cost and adaptability to wide range of machines, equipment and fluids are features of the Murray-Way industrial filter which are outlined in 4-page illustrated bulletin.

38. Production Facilities

Alten Foundry & Machine Works, Inc.—"Here's a Dependable Supplier of Parts and Assemblies for Machinery" is title of 8-page illustrated bulletin that describes facilities of company for providing engineering, weldments, machined castings, complete or subassemblies, and gray or alloy iron castings.

39. Air & Hydraulic Cylinders

Hydraulic Press Mfg. Co., Hydraulic Power Div.—32-page illustrated catalog 701 is descriptive of model 300 series air and hydraulic cylinders for 150-psi air and 300-psi oil service. Bores range from 1½ to 12 in. Both single and double-end piston rod models are available in wide range of mounting styles. Special and special standard modifications and cylinders are covered.

40. Aluminum Mill Products

Reynolds Metals Co.—"1954 Aluminum Mill Products Design" is a 12-page illustrated condensed guide to the use of aluminum wire, rod, tubing, and rolled and extruded shapes. Data are included on characteristics of aluminum, standard alloys, tempers and sizes. Information is given on design and fabrication.

41. Steel Detachable Chains

Chain Belt Co.—44-page booklet No. 52-52 on Rex steel detachable chains covers quality control, manufacture, heat treatment, testing, inspection, storage and shipping phases; gives chain and attachment specs; lists drive and conveyor applications; and provides an engineering section covering chain theory and travel, and sprocket theory and design.

42. Push-Pull Controls

American Chain & Cable Co., Automotive & Aircraft Div.—"The Key To Remote Control" is title of 6-page folder on Tru-Lay push-pull controls and covers the heavy duty micro control V-700 series. Units are designed for micrometer fine adjustment and have instantaneous response.

43. Carbon & Alloy Steels

Empire Steel Castings, Inc.—Designation chart for carbon and low alloy steels identifies company's Isocast carbon and low alloy castings with ASTM, Federal, Navy, AISI and SAE specifications. It also gives chemical analysis, mechanical properties, heat treatment and uses of the 18 steels listed.

44. Prefinished Metals

American Nickeloid Co.—24-page illustrated booklet contains fabrication techniques, uses and properties for such metals as steel, zinc, brass, copper and aluminum with preplated finishes of chromium, nickel, brass, or copper. Standard fabrication techniques such as forming, riveting and welding can be used, a protective coating compound being available to preserve finish during drawing and forming operations.

45. Switches & Actuators

Minneapolis-Honeywell Regulator Co., Micro Switch Div.—Ultra-small type V-3 precision snap-action switches and auxiliary actuators are detailed in 4-page illustrated bulletin No. 74. Contact arrangements, terminals, operating characteristics and electrical ratings are given to aid in design applications.

46. Bronze Bearing Core & Bar Stock

Chrysler Corp., Amplex Div.—More than 700 standard Oilite bearings, cores, bars and plates which are available from stock are listed in 28-page illustrated bulletin S-53. These oil-cushioned self-lubricating bronze bearings can be supplied in any quantity from 1 to 1000 or more.

47. Diesel Engines

Harnischfeger Corp., Diesel Div.—Industrial, marine and motive power diesel engines in 2 to 6-cylinder models and ratings from 20 to 138 hp are described in color-illustrated handy file sheet. Condensed information and specifications are given in separate bulletins on each model.

48. Chain Couplings

Browning Mfg. Co.—Horsepower ratings, revolutions per minute and specifications for a line of chain couplings for American standard roller chain having pearlitic malleable sprockets, hardened teeth and malleable split taper bushings are given in catalog supplement V169B 1-1-54. They are available for bore sizes of up to 2 11/16-in.

49. Flexible Hose & Bellows

Flexonics Corp.—16-page illustrated product design catalog CMH-132 covers flexible metal hose and instrument bellows. Bellows data include material on stainless, brass and bronze bellows and assemblies while complete specifications and application data are provided on corrugated and convoluted hose, as well as details on fittings. Installation instructions are included.

50. Time Delay Relays

Elastic Stop Nut Corp., A'G'A Div. — A complete line of solenoid-actuated, pneumatically-controlled time delay relays is subject of 4-page illustrated bulletin SR-3. These adjustable controls are also available in totally enclosed, auxiliary switch, double head and proportional time delay models.

51. Spectrograph Comparator

Gaertner Scientific Corp.—Used in evaluation and comparison of spectrographic plates by measuring comparative densities and by comparing the unknown plate to a master of known value, model L499 Comparator-Microdensitometer is described in bulletin 190-53. Complete specifications are given on machine, which will accommodate plates up to 4-in. wide x 14-in. long.

52. Variable Speed Drives

Reeves Pulley Co.—Available in both fractional and integral horsepower types, with ratings ranging from ¼ to 30 hp, variable speed motordrives are briefly explained in unusual folder with aid of three-dimensional picture and glasses. Features of representative units from an extensive line are pointed up.

53. Machine Tool Automation

Turchan Follower Machine Co.—"Automation of Machine Tools . . ." is title of well-illustrated 24-page booklet showing typical set-ups for automatic control of machine tools and automatically controlled tools. Principles and methods of putting them into practice are covered thoroughly, and explanations of typical hydraulic servo-control systems are given. Tracer controls and special systems are also shown.

54. Metal-To-Glass Seal

Cerro de Pasco Corp.—Cerroseal-35 is an alloy of indium and tin that softens at 210° F and is liquid above 260° F. It will seal metal-to-metal or metal to glass. It also adheres to mica, quartz, thermosetting plastics and some glazed ceramics. Full information is contained in data sheet E-14.

55. Electric Control Center

Arrow-Hart & Hegeman Electric Co.—Economy, safety and space conservation are features of control centers described in 12-page illustrated bulletin 170. Combination motor starters in this line are half as long as conventional starters. Aid is offered for planning control centers for every need.

56. Rivetless Chain Design

Standard Alloy Co.—Useful as reference material on high temperature conveyor applications, illustrated bulletin No. 2 provides design data and dimensional specifications on cast alloy rivetless chain including both straight and offset-link types.

57. Speed Reducers

Westinghouse Electric Corp.—16-page illustrated booklet B-5646 shows complete line of speed reducers, including right angle and in-line drive types and other special purpose units. Standard ratios available are given and applications, manufacturing techniques and features are discussed.

58. Stainless Steel Products

G. O. Carlson, Inc.—Stainless steel plates, forgings, No. 1 finish sheets, tank heads and flanges and pattern-cut rings and disks are among the products shown in 4-page illustrated bulletin. Company specializes in producing stainless steel parts in any shape or size.

59. Pneumatic Disk Clutch

Wichita Falls Foundry & Machine Co.—No adjustment and smooth engagement are two features of the Wichita Air-Tube disk clutch, described and illustrated in 4-page bulletin 107. Units are made with 8 to 48-in. diameters capable of handling from 6.5 to 2600 hp per 100 rpm. Maximum speeds range from 1750 down to 500 rpm.

60. Electric Brakes & Clutches

Warner Electric Brake & Clutch Co.—Specifications, descriptions, illustrations and dimensional cross sectional drawings of Warner replaceable face electric brakes and stationary field electric clutch-couplings are found in 6-page folder WEB 6158.

61. Hydro-Mechanical Devices

Pathon Mfg. Co.—Oil hydraulic cylinders and hydraulic directional control valves are covered in 32-page illustrated bulletin No. 22. Complete information on various models including tables of sizes and engineering information is given. Cylinders are available in two series for 1000 and 2000 psi oil service.

62. Motor Drive

American Safety Table Co., Inc.—Available in either 1/3 or ½-hp capacities, Power Packed individual motor drives are described as applied to sewing machine duty in illustrated catalog sheet. Design features of unit are fully explained.

63. Mill Drives

General Electric Co.—Rubber and plastic mill drives, featuring enclosed synchronous mill motors with rubber-mill control, are described in 4-page folder GEA-5887. Equipment's advantages and applications are pointed up. Mill motors range from 100 to 1000 hp.

Use 52100 steel for parts like these:

1. Diesel injection pumps
2. Lathe centers
3. Slitting rolls and knives
4. Cam rollers for automotive steering gears
5. Machine tool parts
6. Pump parts
7. Aircraft engine parts
8. Mechanical seals
9. Saw mill rollers
10. Ball bearings
11. Asbestos disintegrators
12. Mill rolls

...and get all these advantages:

1. Hard
2. Tough
3. Machines easily
4. Exceptional wear-resistance
5. High tensile strength
6. Withstands working pressure of 200,000 p.s.i.

BECAUSE it's an alloy steel of high carbon analysis, Timken® 52100 has high tensile and fatigue strength. It's fully spheroidized structure makes machining easier. It has high hardenability throughout its cross section and can be oil quenched to a maximum hardness of 65/66 Rockwell C.

You can get 52100 steel from the Timken Company in all three finished forms: bars, tubes, wire. For your small run or emergency requirements, we maintain a mill stock of 101 sizes of 52100 tubing—from 1″ to 10½″ O.D. We can ship it in less-than-mill quantities within 24 hours after you order.

You're assured of uniform quality in every shipment because we control quality at every step in production. The Timken Company is one of the world's largest producers of 52100 steel, and America's pioneer producer of 52100 tubing.

For a stock list of available sizes, grades and finishes, write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING

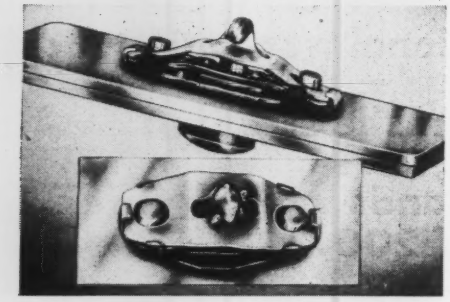
NEW PARTS

AND MATERIALS

For addition information on these new developments, see Page 223

Locking Fastener

Hi-Strength model HO quick locking and opening fastener is a one-piece stud without cross pins,



milled sections or holes. It locks with a quarter turn clockwise and unlocks in the opposite way. Shear load strength is 4750 lb; tensile strength, 3000 lb; locking torque, 8.5 in.-lb; unlocking torque, 6.0 in.-lb. Shear load is distributed evenly around area of fastened parts. Misalignment between sheets being fastened can be 0.125-in. Fastener is 0.680-in. wide, 0.407-in. high; spring assembly is 1.490 in. long, with 1-in. rivet centers. Made by **Lion Fastener Inc.**, N. Main St., Honeoye Falls, N. Y.

For more data circle MD-64, Page 223

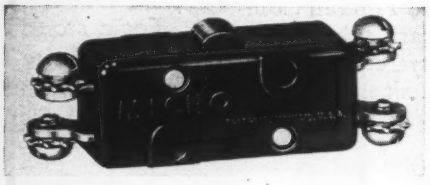
Plastic Hose, Pipe

Lightweight Fluoroflex-T pipe and hose handles corrosive liquids at temperatures from −100 to 450 F without physical, structural or visual changes. Made of DuPont Teflon, products have high tensile strength and almost unlimited shelf life. Hose is offered in seven sizes from ¼ through 1 in. Pipe, which is lamination of fluorocarbon resins with glass fabric, is available in 1, 1½, 2, 3 and 4-in. diameters. Special sizes can be produced. Made by **Resistoflex Corp.**, 39 Plansoen St., Belleville 9, N. J.

For more data circle MD-65, Page 223

Two-Circuit Switch

Model 1TB1-1 Micro Switch, measuring ½ x ½ x 1¼ in., is suited for reversing circuit applications in limited space. Contact arrangement is single-pole, double-throw, two-circuit double-break. One normally open and one normally closed screw terminal ex-

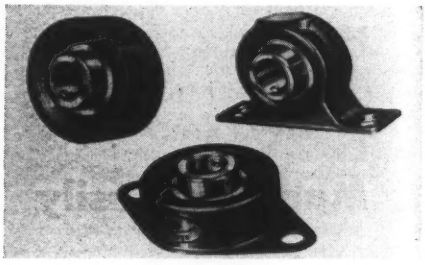


tend from each end of the phenolic case. These terminals are plated for soldering if the switch is used without terminal screws. Two 0.101-in. diameter holes on a 0.520-in. center permit mounting of the switch in a fixed position. Switch is electrically rated for 10 amp at 125 or 250 v ac or 30 v dc, inductive. Made by Micro Switch Div., **Minneapolis-Honeywell Regulator Co.**, Freeport, Ill.

For more data circle MD-66, Page 223

Ball Bearing Units

Rubber mountings in pressed steel housings minimize noise and vibrations in Sealmaster ball bear-



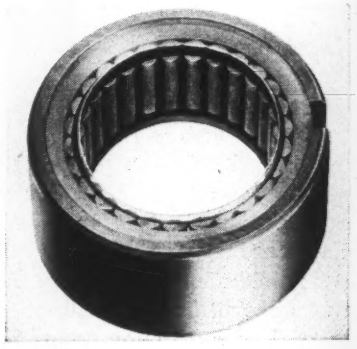
ings. Six shaft sizes from ½ to 1 in. are available as pillow blocks, flange and cartridge units. Bearings are adaptable for use on light duty applications. Synthetic rubber mounting rings are oil and grease resistant and bearings are factory lubricated for life. Ball path section of inner race ring is zone hardened. Bearing units are grounded to the housing to prevent build-up of static charge. Made by Sealmaster Div., **Stephens-Adamson Mfg. Co.**, Aurora, Ill.

For more data circle MD-67, Page 223

Cam Clutches

With outside dimensions and tolerances corresponding to seven sizes of standard 200 series ball bearings, 200 series cam type one-way clutch units serve as backstop (antirotation), indexing and overrunning clutches in a variety of machine drives. Clutch has no

inner race, the full complement of cams bearing directly on a hardened shaft surface. Shaft on which the cams bear rotates in one direction only. As an indexing unit, cam clutches act as self-contained ratchets. In general overrunning applications they engage instantly when torque is applied and disengage when torque ceases. Clutches fit bores from

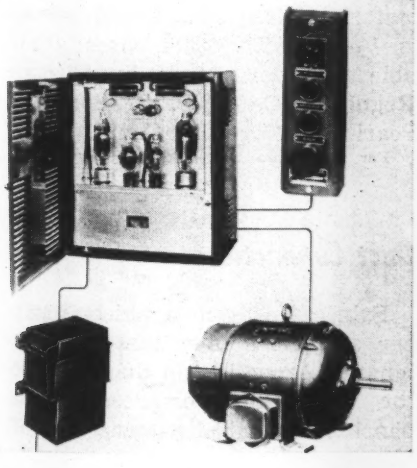


1½ to 3½ in. and are from 1 to 1¼ in. long. Free wheeling speed without excessive temperature rise is up to 2000 rpm. Torque ratings, when used as backstop unit, are from 30 to 500 lb-ft. Made by **Morse Chain Co.,** 7601 Central Ave., Detroit 10, Mich.

For more data circle MD-68, Page 223

Adjustable Speed Drive

Stepless electronic Select-A-Spede drive operates from ac power lines and is available with ¾ to 15-hp dc drive motors in standard NEMA frame sizes. Unit offers precision speed control, wide speed range where required, adaptability to a variety of op-

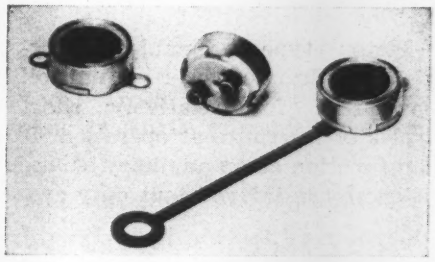


tional electrical and mechanical modifications, and the use of simple electronic circuits. Speed ranges are 5:1, 20:1 or 50:1, with 100:1 available for some applications. When used with optional tachometer feedback equipment, unit's speed regulation is ±½ per cent. Optional controls include inching, jogging, threading speeds, acceleration and deceleration, dynamic braking, and reversing. Complete unit consists of an anode transformer, electronic control panel, pushbutton station, and adjustable speed dc drive motor. Made by **Louis Allis Co.,** 427 E. Stewart St., Milwaukee 7, Wis.

For more data circle MD-69, Page 223

Fast-Action Thermostat

Stemco type A thermostat provides close control of temperatures in electronic, appliance and industrial apparatus applications. It is a quick make-and-break unit with a disk type bimetal thermal element close to the controlled surface for fast action. Current is



carried through a copper contact spring which is insulated from the element. Thus fewer contact operations are performed and false cycling is eliminated. Maximum operating temperature is 400 F, and temperatures as low as −60 F do not impair normal operation. Made by **Stevens Mfg. Co.,** 69 S. Walnut St., Mansfield, O.

For more data circle MD-70, Page 223

Seat Rings

Fabricated from carbon, stainless or tungsten die steels and hard faced at points of wear and impact with stellite overlays which vary in depth from 0.060 to 0.090-

in., seat rings are available in 1 to 14-in. diameter sizes, to meet specified tolerances. Overlay is of uniform hardness and has good wear, heat and corrosion resistant characteristics. Made by **Cleveland Hard Facing Inc.,** 3047 Stillson Ave., Cleveland 5, O.

For more data circle MD-71, Page 223

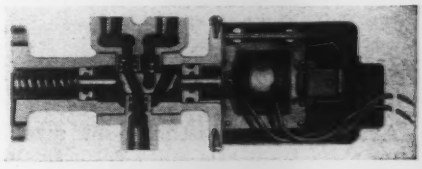
Plastic Coating

Made of Bakelite vinyl resin-base plastisols, corrosion resistant coatings protect machine parts from acids, alkalies, moisture and mineral salts and inhibit rust, blistering and deterioration of metal surfaces. Applied in uniform thicknesses ranging from 1/32 to 3/16-in. and then fused by baking, the coating is abrasion resistant and highly adhesive to metal surfaces. Made by **Quelcor Inc.,** Front and Broomall Sts., Chester, Pa.

For more data circle MD-72, Page 223

Solenoid Valves

Series of Shear-Seal valves is designed for 0 to 250 psi oil service. Valves are not critical to pipe scale or other foreign material in



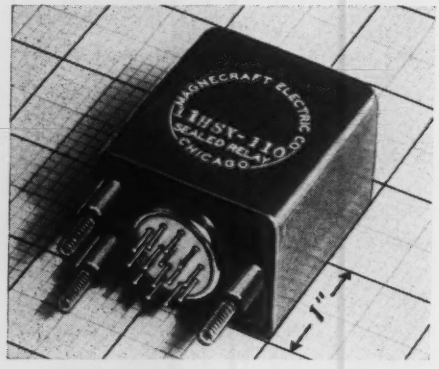
the liquid, because lapped sealing members are in constant intimate contact. Square corner wiping ac-

tion pushes dirt aside for removal through the return port. Eroding and scoring do not occur, because flow is through the sealing members and not across the sealing surfaces. Pipe sizes of ¼, ⅜ and ½-in. are available in four-way and three-way shut-off models for 110, 220 or 440 v ac. Made by **Barksdale Valves,** 5125 Alcoa Ave., Los Angeles 58, Calif.

For more data circle MD-73, Page 223

DC Relays

Small direct-current relays meet application requirements in limited space and are hermetically

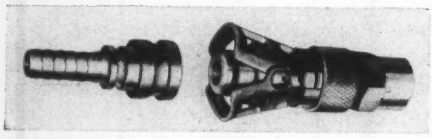


sealed in a metal container measuring 1⅛ x 1 9/16 x 1 13/16-in. high. Available with 14-pin miniature plug or solder terminals, they comply with military specifications and resist shock, vibration and wide temperature fluctuations. Supplied for any voltage up to 115 v dc with contact combinations up to four-pole, double-throw. Resistance range is 0.12 to 11,000 ohms and weight is approximately 5 oz. Made by **Magnecraft Electric Co.,** 1442-M W. Van Buren St., Chicago 7, Ill.

For more data circle MD-74, Page 223

Valve Coupling

Available in ¼ to ¾-in. sizes with hose connections or male or female pipe threads, Quick-As-Wink valve coupling can be used with air pressure up to 250 psi. Nose piece of the jaw half of the coupling is provided with an O-ring held in a machined groove.

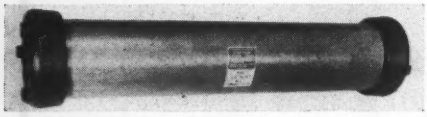


When the coupling is connected, the nose piece slides into the recess of the connection half of the coupling, and the joint is tightly sealed, even though the two halves can swivel freely without leakage. Jaw or valve half of coupling which is permanently connected to the live air supply line has locking jaws and a brass sleeve. Jaws cannot be opened and coupling cannot be disconnected while the sleeve is in "on" position or when it is locked in "off and exhaust" position. Made by **C. B. Hunt & Son Inc.,** Salem, O.

For more data circle MD-75, Page 223

Hydraulic Accumulator

Piston type accumulator furnishes hydraulic power at high oil flow rate for relatively short cycles of intermittent operation. It can function as an auxiliary source of energy in intermittent duty sys-

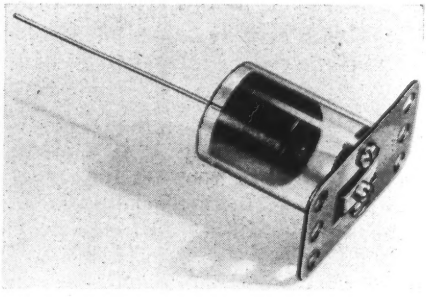


tems, an emergency source of fluid power for operation of a secondary hydraulic system, a surge chamber or shock absorber, a leakage compensator in a closed or pressure regulated circuit, a thermal expansion compensator, or a dispenser of fluids under pressure. Eleven sizes are available, with bores of 1½, 4 and 7 in., in lengths varying from 9⅜ to 40 in. Oil volume capacities range from 10 to 1155 cu in., and operating pressure rating is 3000 psi. All accumulators are of single shell design, the shell being made of seamless steel tubing. Internally threaded end caps are forged steel, piston is aluminum, and seals are Parker O-rings. The use of alignment rings to support the piston results in low frictional wear and minimum leakage of O-rings. Made by Industrial Hydraulics Div., **Parker Appliance Co.,** 17325 Euclid Ave., Cleveland 12, O.

For more data circle MD-76, Page 223

Air-Damp Dashpot

Weighing less than ½-oz, this precision air-damp dashpot for use as a system stabilizer in control mechanisms and switchgear provides mechanical damping and shock absorption. Dashpot is made of low expansion glass cyl-



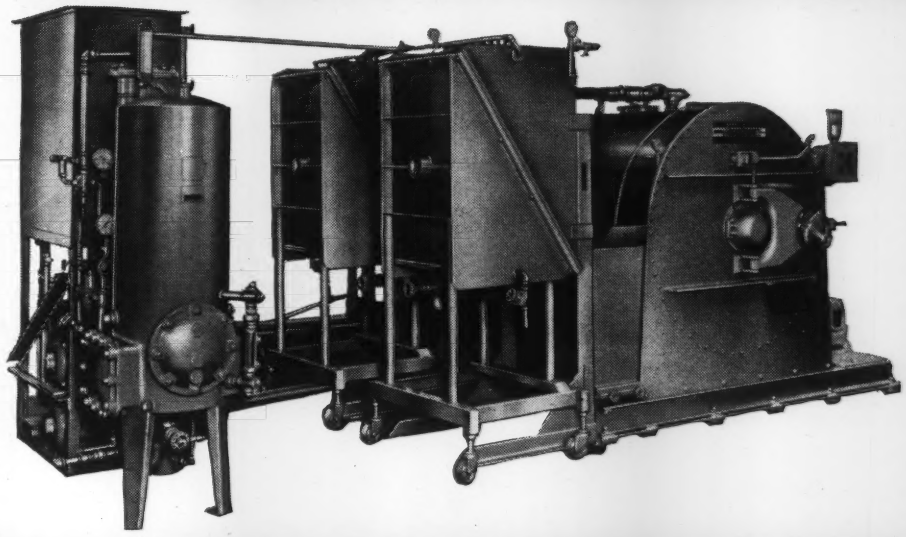
inder and graphitized-carbon piston, ground and fitted to tolerances closer than 0.002-in. It has a metal plate for mounting and operates in any position at temperatures from −75 to 150 C. Damping constant is adjustable up to 0.06-lb-seconds per inch, and maximum tension force is 4 lb at sea level. Compression force is limited only by strength of the materials used. Maximum stroke is ½-in., with other sizes available to order. Made by **Electric Regulator Corp.,** P. O. Box 689, Pearl St., Norwalk, Conn.

For more data circle MD-77, Page 223

Duct Connector

Fabricated from a silicone rubber and glass fiber material designated ArcoSil, this duct connector withstands compression, expansion and misalignment and of-

HOW TO CLEAN WITH SUPER-STRONG SOLUTIONS



another successful product design with piping equipment by CRANE

Bring on your toughest dry cleaning jobs—this specially designed *Trucleen* unit by The American Laundry Machinery Co., of Cincinnati uses soap solutions 5 to 50 times stronger than previously possible. Featuring an automatic two-bath operation, the unit handles 105 pounds of work each 40 minute cycle.

Like many manufacturers, The American Laundry Machinery Co. designed piping dependability into their product by specifying from the familiar Crane Catalog. And it's a time saver, too, containing full information on the world's most complete selection of quality piping . . . with sizes and dimensions, temperature and pressure ratings, plus helpful details on materials and construction.

Crane Packless Diaphragm Valves . . . find ready application in products of all kinds. Crane design assures long diaphragm life, positive shut-off in case of diaphragm failure, accurate seating, better flow control. They're easy to operate . . . simple to maintain. Specify your choice of body materials, trim materials, and linings. Unlined valves available with screwed or flanged ends. Lined valves, flanged ends only. Sizes up to 6-inch.

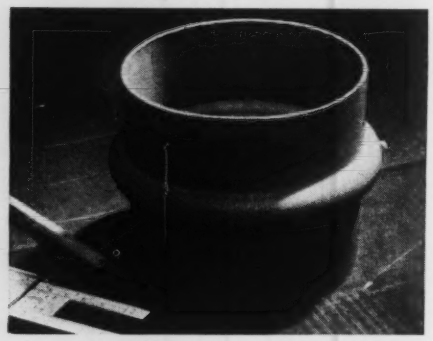
YOU'LL FIND IT HERE ...IN YOUR CRANE CATALOG

THE BETTER QUALITY... BIGGER VALUE LINE... IN BRASS, STEEL, IRON

CRANE VALVES

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING



fers resistance to high pressures and to operating temperatures from −100 to 700 F and higher. Because it is highly flexible under all conditions, the connector withstands the effects of vibration and torque motions. Standard hose clamps are used for most installations. Made by **Arrowhead Rubber Co.**, 2350 Curry St., Long Beach, Calif.

For more data circle MD-78, Page 223

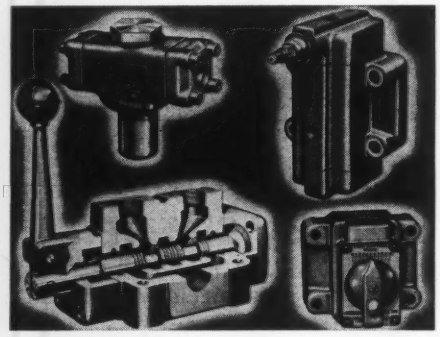
Vacuum Tube Voltmeter

Type A vacuum tube voltmeter, measuring 3½ in. in diameter and 4½ in. deep, is designed for incorporation in production test equipment, as well as in lightweight, airborne or portable electronic equipment. It is available with full-scale sensitivities ranging from 10 mv to 300 v rms. With input impedance of 1 megohm and accuracy of 3 per cent, the meter can be used for measurements from 20 to 50,000 cycles per second. Utilizing a feedback amplifier circuit, it incorporates subminiature vacuum tubes. For linearity and stability, four germanium diodes are used in the meter bridge circuit. Made by **Trio Laboratories**, P. O. Box 143, Wantagh, N. Y.

For more data circle MD-79, Page 223

Hydraulic Valves

Characteristics of line of over 3500 hydraulic valves include full-floating operating lever on directional valves to give actual "feel of the control," O-ring seals on each end of valve body, minimum pressure drop, selectively fitted spools, machined inlet and cylinder ports, and interchangeable end caps. Directional valves are offered for threaded, flange and gasket

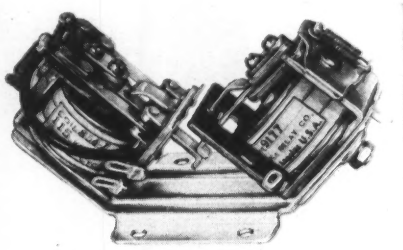


mounting for maximum pressures up to 3000 psi. Functional units include relief, sequence, unloading, pressure reducing, counterbalance, flow control and check valves, for pressures up to 3000 psi, depending upon type of connection. Each type is available with optional body styles, types of control, methods of operating and other features for universal application. Made by **Hydraulic Press Mfg. Co.**, Hydraulic Power Div., Lincoln Ave., Mt. Gilead, O.

For more data circle MD-80, Page 223

Latching Relays

Compact, lightweight, vibration and shock resistant relays can be mounted in any position. Coil mechanism is angle mounted. Wedge action utilizes latch faces with slight radius plus end-to-end operation of latch mechanism to assure positive latching regardless

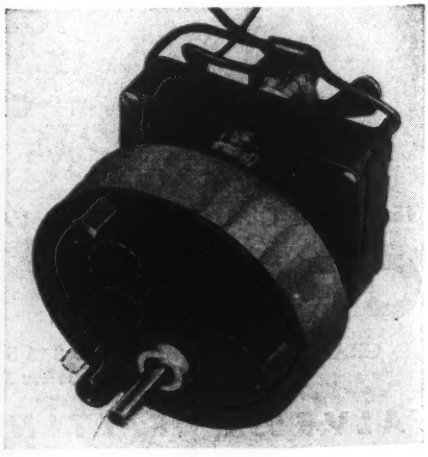


of wear or play in armature hinge joints. Type 9177 relay has double-pole, double-throw contacts; type 9179 has four-pole, double-throw contacts. Contact rating is 8 amp at 115 v ac noninductive or 29 v dc resistive load. Coils for continuous or intermittent duty are rated 120 v ac or dc with resistances to 10,000 ohms. Relay measures 3 11/16 x 1⅞ x 1 11/16 in. Made by **Leach Relay Co.**, 5915 Avalon Blvd., Los Angeles 3, Calif.

For more data circle MD-81, Page 223

Offset Driveshaft

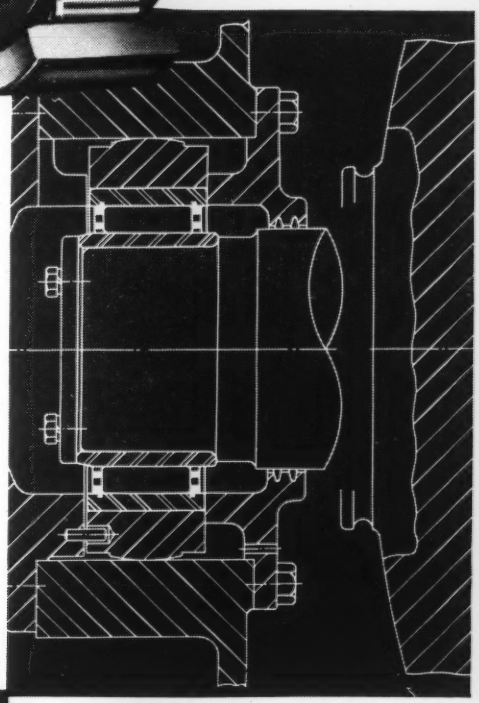
Series 500 small, fractional-horsepower motors now have offset driveshafts, which permits mounting in hard-to-reach places. Shaft can be brought out of gear housing at any one of five different locations, including standard center takeoff. Shaft speeds range from one revolution in three days to 600 rpm. Shafts up to 2½ in. long can be supplied, standard length being 1 in. Series 500 motors are synchronous or nonsynchronous induction type operating on alternating current only. Speed



Is shaft expansion a problem?

HERE'S HOW HYATTS HELP...

Hyatt Hy-Loads are available in separable outer race, separable inner race or non-separable construction.



Check the drawing at the left. The bearing is a Hyatt Hy-Load, and because the inner race is cylindrical, the shaft it supports is free to move axially—thus allowing for shaft expansion without cramping the bearing or distorting the shaft. Obviously, this is only one of many ways in which Hyatt bearings can be used to reduce costs as they reduce friction, but it's a good example of why so many designers throughout industry keep their Hyatt catalogs within easy reach.

For further details write for Catalog 150 or call your nearest Hyatt representative.

HYATT ROLLER BEARINGS

STRAIGHT BARREL TAPER

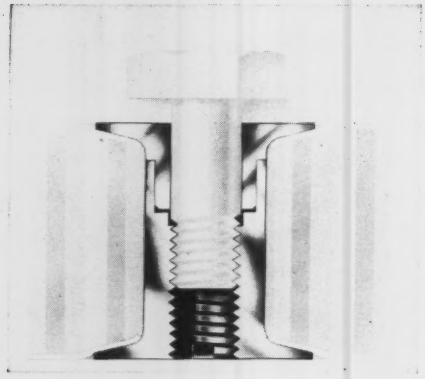
HYATT BEARINGS DIVISION • GENERAL MOTORS CORPORATION • HARRISON, NEW JERSEY

of former is 1800 rpm. Motors can be stalled indefinitely without damage to wiring or overheating and will operate under load continuously for long periods. Available with various torques. Made by **Gleason-Avery Inc.**, 29 Clark St., Auburn, N. Y.

For more data circle MD-82, Page 223

Spacer Assembly

Fasco threaded spacer assembly for sandwich type structure fastening incorporates a tapped sleeve which receives the attaching bolt and eliminates the need for a nut. Design lends itself to use with

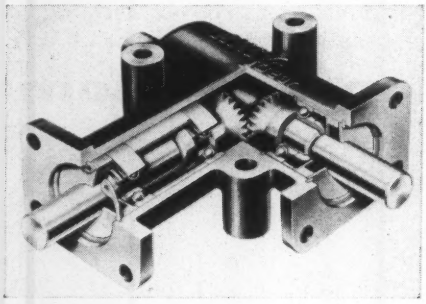


fragile constructions where take-up distance must be positively limited to prevent crushing. Spacers are for light load applications, and are available with a variety of thread numbers and sizes in grip lengths from ⅜ to 1¼-in. They are fabricated from anodized aluminum alloy and can be installed without special tools. Made by **Delron Co. Inc.**, Fasco Div., 5224 Southern Ave., South Gate, Calif.

For more data circle MD-83, Page 223

Right-Angle Gear Drive

Substitution of Coniflex bevel gears for straight tooth gears in Anglgear standardized right angle gear drives provides quieter, cooler operation and longer service life. Small, compact units have high load capacity and are suited for use in powered systems or for

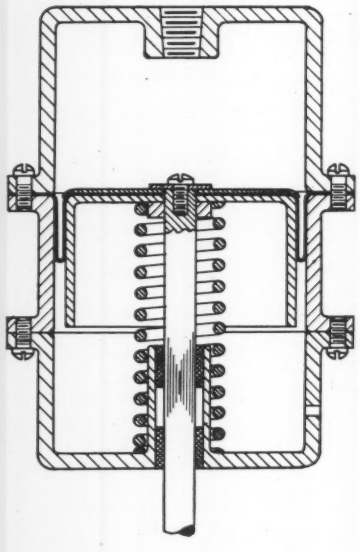


manual operation. Sealed ball bearings are lubricated for life. Installation can be in any position and rated speed is 1800 rpm. Models are made in two-way or three-way styles. The 1/3-hp unit is rated at 250 in.-lb, or 500 in.-lb if extra capacity gears are used. Larger 1 hp unit, measuring 6 x 5 x 2 in., is rated at 1500 in.-lb ultimate static torque capacity. Made by **Airborne Accessories Corp.**, 1414 Chestnut St., Hillside 5, N. J.

For more data circle MD-84, Page 223

Piston Seal

Bellofram combines functions of bellows and diaphragm. Characteristics include long stroke, deep convolution, constant area diaphragm, long flexing life and low spring gradient and response to small changes in pressure. Fric-

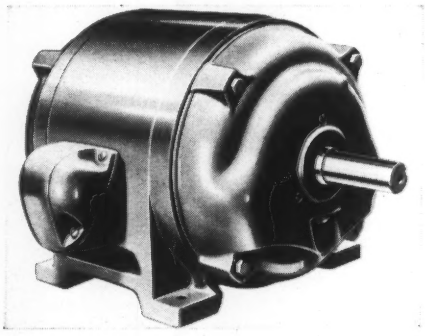


tionless, free positioning and relaxed at all points within its stroke, seal operates at pressures ranging from ¼-in. water to 500 psi and over a wide temperature range. Three classifications of application are: for repeatedly converting gas or liquid pressure into a corresponding force or displacement, for converting pressure into a long stroke at high thrust levels without mechanical friction, and for preventing leakage of gas or liquid across a moving piston or shaft without introducing mechanical friction or spring gradient. Made by **Bellofram Corp.**, 144 Moody St., Waltham, Mass.

For more data circle MD-85, Page 223

Dripproof Motor

Compact, dripproof and dustproof, Uniclosed type H motor is available with solid, one-piece cast



iron frame in 182-184 sizes. Air intakes on end brackets are arranged to prevent entrance of water, yet allow air flow into motor for two-way ventilation. Slot design of laminations has been improved, and asbestos-protected windings are reinforced and strengthened. Split dome terminal box makes leads accessible. Lubriflush lubrication of bearings allows replacing grease without disassembling motor or disturbing bearings. Made by **U. S. Electrical Motors Inc.**, P. O. Box 2058, Los Angeles 54, Calif.

For more data circle MD-86, Page 223

Air, Hydraulic Cylinders

Several hundred popular combinations of bore, stroke and mounting are available from stock in line of air and hydraulic cylinders. Noncushioned models available are 2,

FREE! time-saving slide rule...

helps you design the advantages of

ALEMITE OIL-MIST

into any machine...in minutes!

Here's the simple, easy way to specify Alemite Oil-Mist—to make sure your machines have the tremendous advantages offered only by this most modern method of lubrication.

It's easy to measure the lubrication requirements of *any* machine you are designing! Just set the Oil-Mist slide rule as required—for anti-friction bearings, plain bearings, slides, ways, vees, chains or gears—and immediately the proper application information appears.

You see at a glance the type of fitting to use—how to compute bearing surface—how to take full advantage of the amazing capacity and flexibility Oil-Mist offers you! Includes basic lubricant recommendations and a complete schematic diagram showing tubing, fittings, tees, unions.

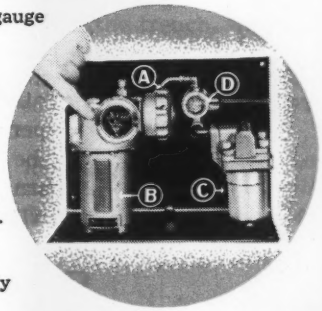
Save time and work in specifying and detailing Oil-Mist, the most efficient machine lubrication ever devised! Clip, fill out and mail coupon NOW. Supply limited!

Alemite Oil-Mist offers these lubrication advantages

Automatic Lubrication • Continuous Lubrication
Eliminates Guesswork • Greater Safety • Cuts Oil Consumption up to 90%
Extension of Bearing Life • Stops Oil Drippage • Reduction of Bearing Temperatures • Manpower Savings • Elimination of "Down-Time"
Reduction in Number of Lubricants • Protection from Contamination

LUBRICATOR SPECIFICATIONS:

- Oil-Mist outlet ½" fem. p.t. Air gauge registers to 50 psi. Operating air pressure—5 to 20 psi.
- Air regulator (A) reduces from pressures up to 200 psi. Normal air consumption—.7 to 1.2 cfm.
- Range of oils handled—to 1,000 sec. (S.U.V.) @ 100°F.
- Oil reservoir (B) capacity 12 oz. (approximately 1 week supply). Intake filter screen—70 mesh. Fill plug—9/16".
- Material—die cast aluminum body with nylon plastic window.
- Baffle-type water separator (C)—automatic self-dumping. Requires no manual attention—no filter elements to replace. Air inlet ¼" fem. p.t.
- Solenoid Control (D) starts system automatically when machine starts—foolproof.



A PRODUCT OF SW STEWART WARNER

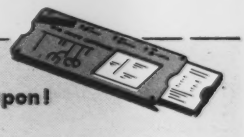
Alemite OIL-MIST Lubrication

Delivers Oil to Bearings 3 Ways!

Oil-Mist Fittings bring the most efficient lubrication in the world to any anti-friction bearing—ball, roller or needle.

Spray Fittings are recommended for open and enclosed gears and chains. Allow for a concentrated spray of oil where it is needed.

Condensing Fittings apply oil in liquid form to plain bearings, slides, ways, vees, cams and rollers.



FREE! Fill out—mail this coupon!

ALEMITE, Dept. R-44
1850 Diversey Parkway, Chicago 14, Illinois

Gentlemen: Please send me my Oil-Mist Slide Rule and up-to-date information on Oil-Mist. No obligation.

Name_____

Company_____

Address_____

City_____ State_____

Request

PLUG-INS

THE UNIVERSAL SELENIUM RECTIFIERS

Rectifier failures are infrequent—**BUT**—here is a power rectifier that can be replaced on a moment's notice without tools. Bring your equipment up to date by installing Sarkes Tarzian Plug-In Rectifiers. Our engineers will design these rectifiers for your application. Please send us your requests.

New 72-page Selenium Rectifier Handbook Available. Latest Engineering Information. Send For Your Copy. Price $1.00.

Sarkes Tarzian, INC.

RECTIFIER DIVISION

415 N. College Ave., Dept. Y1, Bloomington, Indiana

In Canada - 50 St. Clair Ave., N. W., Toronto

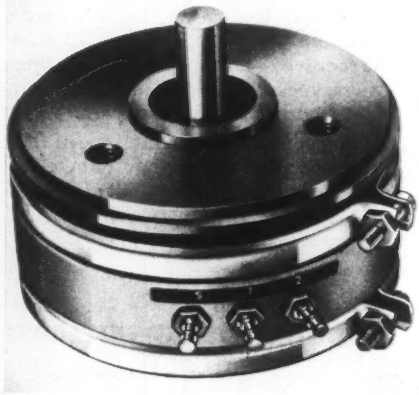
New Parts

2½, 4 and 6-in. bore air cylinders and 1½, 2½ and 4-in. bore hydraulic cylinders, each available in 2, 4, 6, 8 and 11-in. strokes. Models cushioned at both ends are 2 and 3¼ in. bore hydraulic cylinders and 2, 3¼, 5 and 8-in. bore air cylinders, each available in 3, 5, 7, 9 and 13-in. strokes. Air cylinders are rated for 200 psi operation; hydraulic type, for 2000 psi. Base model of stock cylinders is model 53 with threaded tie rods extended at rod end. Mounting attachments are available as desired, for quick conversion to flange, foot or pivot mounting. Made by **Miller Motor Co.**, 2040 N. Hawthorne Ave., Melrose Park, Ill.

For more data circle MD-87, Page 223

Potentiometer

Providing resistance from 2 to 100,000 ohms with tolerance as close as ±1 per cent, J series Helipot precision single turn continuous-rotation potentiometer is designed for servo mounting and



is rated at 4 w at 40 C ambient temperature. Up to 21 extra taps can be added, each spot-welded to a turn of resistance wire without shorting out adjacent turns. As many as six sections can be ganged on one shaft. Potentiometer has 2-in. diameter, with overall length for a single section of 1 19/32-in. Additional ganged sections add 39/64-in. to the overall length. External metal clamps permit rapid phasing of any section, even after installation. Series is available with either ball or

dig this powerful ditcher

PHOTO COURTESY BARBER-GREENE COMPANY, AURORA, ILLINOIS

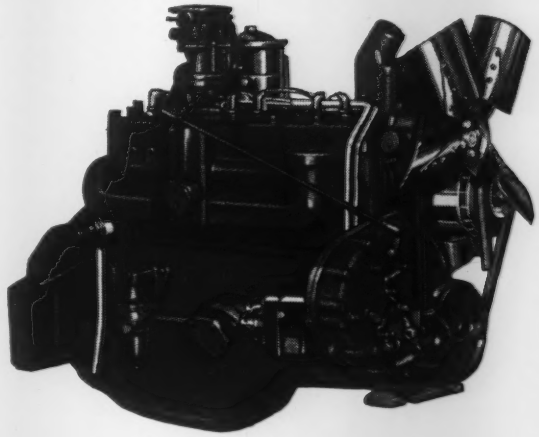
Chrysler *power and gýrol Fluid Coupling team up to put the "run" in runabout.*

When the operator of this ditcher "lowers the boom" things happen fast. That's because the vertical boom concentrates the weight of the unit on the work, bringing additional pressure to bear on digging buckets. This, in turn, allows them to bite into practically any kind of ground formation, frozen soil or even bituminous pavement. Upon completion of digging, a simply-operated hydraulic control raises the boom and the unit takes off—automotive style—down the highway to the next job.

Behind the power and dexterity of the Barber-Greene Runabout is the Model 8 Chrysler Industrial Engine and Chrysler gýrol Fluid Coupling. This 250 cubic inch displacement engine with its wide speed range drives the bucket line, crowds the ditcher along the trench, supplies power to the hydraulic boom hoist and takes the ditcher to the next job at traffic speeds. Chrysler gýrol Fluid Coupling helps the operator coordinate crowding and bucket line speeds for maximum digging efficiency.

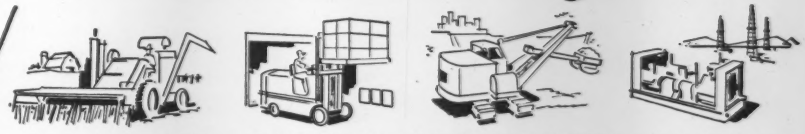
If your equipment requires power within our 217 to 413 cubic inch displacement range, engines that will operate equally well with gasoline, natural or L-P gas fuels, engines ideally suited to power take-off, then see a Chrysler Industrial Engine Dealer. He can supply *engines equipped at the factory for their jobs in the field.*

Remember too that Chrysler Power is not expensive. Production-line methods adapted to specialized industrial engine building provide a custom-built engine at mass-production prices. If you prefer, write: ***Dept. 64, Industrial Engine Division, Chrysler Corporation, Trenton, Michigan.***



CHRYSLER *Industrial Engines*

HORSEPOWER WITH A PEDIGREE



AGRICULTURE • INDUSTRY • CONSTRUCTION • OIL FIELDS

One Call Does It All!

A call to MD brings you direct to Metal Powder Headquarters and closer to the answer to your Powder Metallurgy problem.

For, as a pioneer in the manufacture of metal powders since 1916, MD has played a large role in the development of many of their uses in industry today as the *only* company which manufactures a complete line of metal powders. This has resulted in MD being the first source called on to supply an extensive line of powders for a wide range of applications.

Call on "Metal Powder Headquarters" for help on your metal powder problems. The advice and recommendations of the MD Sales Service Department are yours without obligation.

METALS DISINTEGRATING COMPANY, INC.
Elizabeth B • New Jersey

MD POWDERS
METAL POWDERS
METAL PIGMENTS
METAL ABRASIVES

See the
MD EXHIBIT
at the
METAL POWDER SHOW
Drake Hotel,
Chicago, Ill.
April 26-28, 1954

2125

SUBSIDIARY OF AMERICAN-MARIETTA COMPANY

WORLD'S LARGEST MANUFACTURER OF FINELY DIVIDED METALS

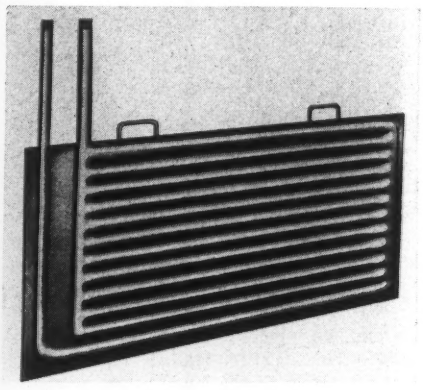
New Parts

sleeve bearings. Made by **Helipot Corp.**, 916 Meridian Ave., South Pasadena 21, Calif.

For more data circle MD-88, Page 223

Heat Exchange Coil

Lightweight Thermo-Panel plate type coils for heating and cooling are available in standard and special sizes and shapes and in a wide range of materials including

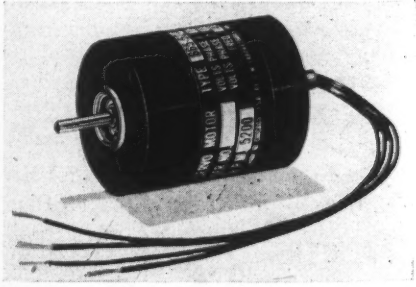


stainless steel, Monel, and other special alloys and finishes. They are available in parallel type for steam application or in series type for heating and cooling fluids. Made by Thermo-Panel Div., **Dean Products Inc.**, 616 Franklin Ave., Brooklyn 38, N. Y.

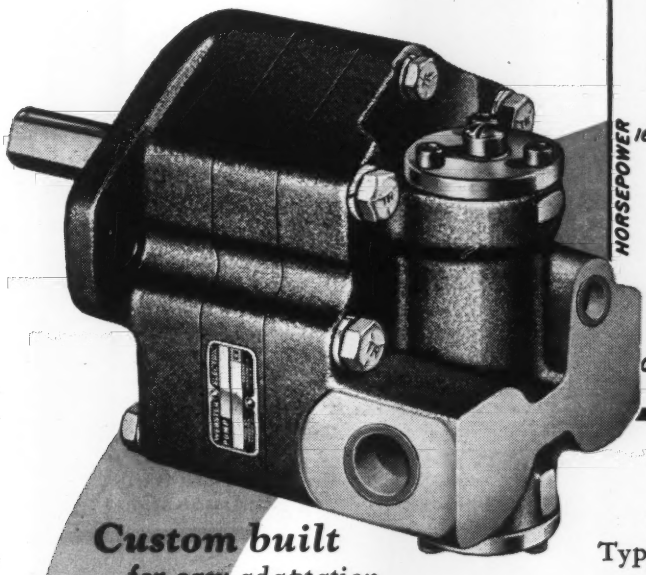
For more data circle MD-89, Page 223

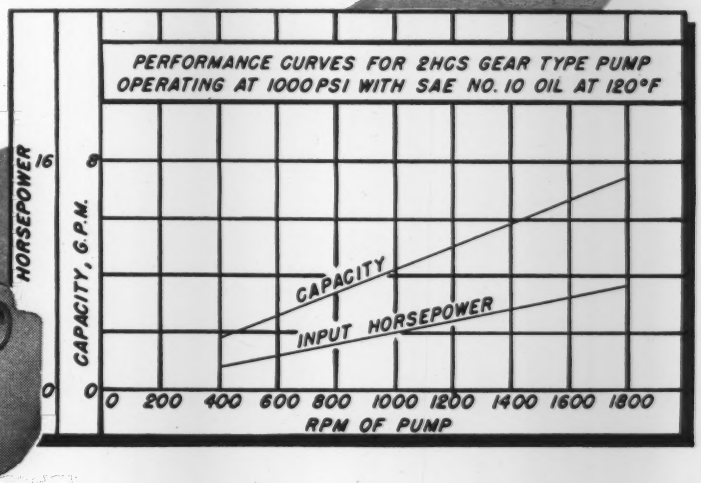
Servo Motors

High precision type 52 servo motors are available in a wide variety of speeds and electrical characteristics. Measuring 1½-in. in diameter, they can be supplied to meet military specifications of humidity, temperature, vibration and al-

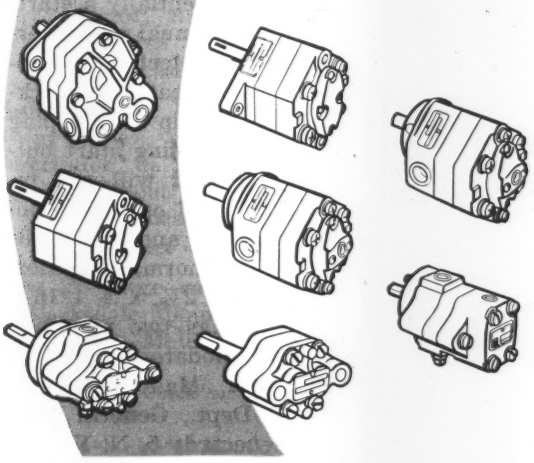


Check this typical **WEBSTER** Hydraulic Pump Performance Curve





Custom built *for easy adaptation to your system*

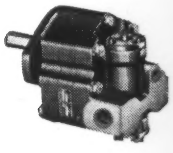


• It will pay you to get the facts about WEBSTER Gear-Type Hydraulic Pumps before buying any pump. Here is a complete line of rugged, dependable pumps from 10 gph. to 10 gpm., engineered to operate efficiently at pressures up to 1200 psi. at speeds of 3600 rpm. or less—90 types of WEBSTER Oil Hydraulic Pumps of various designs and capacities to meet the widest range of requirements!

• WEBSTER pumps are the product of skill acquired during nearly a quarter-century of experience. They have established an enviable reputation for efficient, dependable operation. All WEBSTER pumps lend themselves readily to many forms of adaptation—and to modification for special installations. All are available with built-in relief valve, if desired.

• Whenever you require pumps for lubricating, oil circulating, filtering, transfer or quiet hydraulic power applications, we invite your inquiries.

Write *today for catalog containing performance charts and pump data sheets on which you can describe your requirements*



OIL HYDRAULICS DIVISION

WEBSTER ELECTRIC

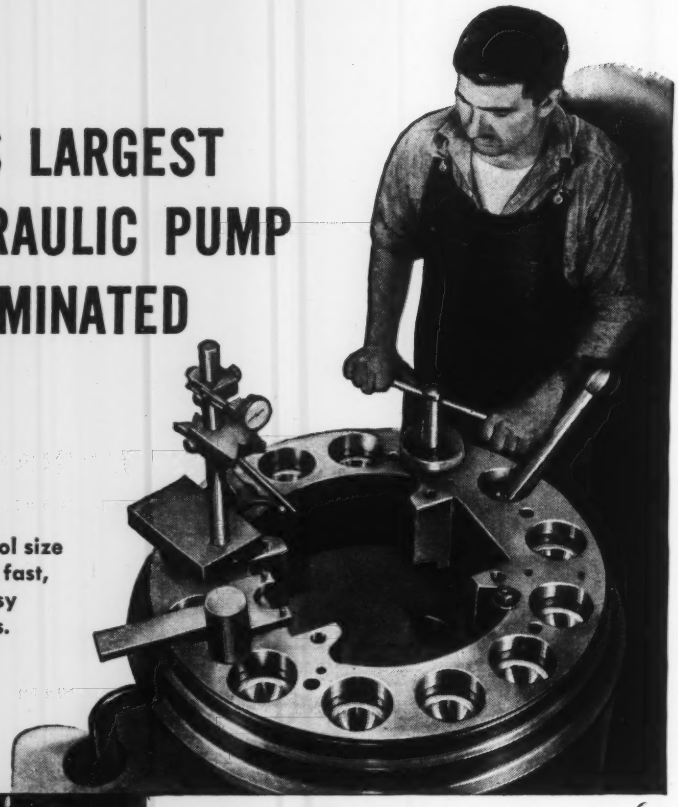
RACINE, WISCONSIN

ESTABLISHED 1909

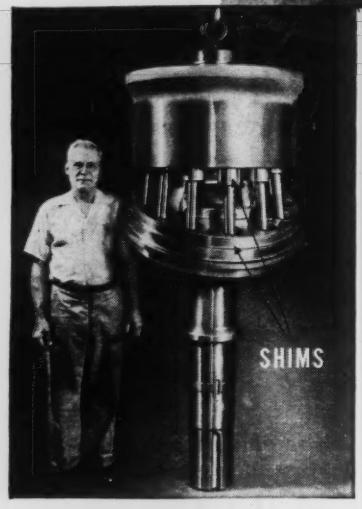
"Where Quality is a Responsibility and Fair Dealing an Obligation"

MANUFACTURERS OF A COMPLETE LINE OF OIL HYDRAULIC PUMPS

WORLD'S LARGEST OIL HYDRAULIC PUMP USES LAMINATED SHIMS



New Waterbury Tool size "300" pumps gain fast, accurate fit and easy service adjustments.



Heart of this huge 20-ton hydraulic pump is the immense revolving assembly of angle plate, connecting rods and pistons. Tilting the angle plate permits rapid reversing under heavy load. Both ends of the connecting rod bearings – at angle plate and pistons – are assembled and adjusted with Laminated Shims. Shown in large picture is angle plate being assembled. Smaller picture gives size of complete revolving assembly. Pumps will be used in Tube Reducing Machine being built by E. W. Bliss Co. for the Tube Reducing Corp.

The largest oil hydraulic high pressure pumps ever built presented a host of new engineering problems—but the old, familiar problems of fast accurate assembly and easy service adjustments were solved by the old familiar remedy . . . *laminated shims!*

For laminated shims in steel, stainless steel, brass, aluminum and combinations of metals call us first! Forty years of shim engineering experience are at your service! Please write for further information and our new catalogue, yours without cost or obligation.

Simply P-E-E-L for adjustment.

SHIM HEADQUARTERS SINCE 1913

Check Our Stampings Division
For Your Stamped Parts Requirements

LAMINATED SHIM COMPANY, INC.

1204 UNION STREET • GLENBROOK • CONNECTICUT

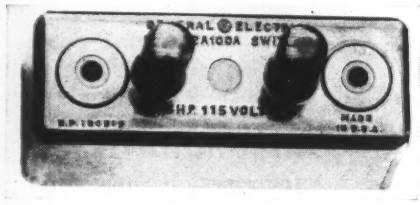
New Parts

titude. Stators are embedded in an insulating compound of high dielectric strength which is stable at elevated temperatures. Housings are stainless steel or aluminum and ball bearings are stainless steel or SAE 52100 steel. Rotors are centrifugally cast and laminations are of high nickel steel. Made by **G-M Laboratories Inc.**, 4300 N. Knox Ave., Chicago 41, Ill.

For more data circle MD-90, Page 223

Starting, Overload Switch

For applications requiring line current overload protection, fractional-horsepower motors can be controlled with this manual starting and overload switch. Totally



enclosed unit is essentially a start-stop switch with manual reset overload. Overload protection is provided by nichrome heater and nickel-alloy bimetal strip in tripping mechanism. Depressing start button during overload will not re-energize motor until overload condition is removed and bimetallic strip returns to normal position. Control measures 2⅞ x 1 1/16 x 1 3/16 in. and has two mounting holes to accommodate No. 6 self-tapping screws. Made by Appliance Control Dept., **General Electric Co.**, Schenectady 5, N. Y.

For more data circle MD-91, Page 223

Indexing Mechanisms

Indexers now have integral shock control units which provide constant, uniform feed while allowing maximum speeds without danger of damage to mechanism or work. Rear view illustration shows piston of control unit, at upper right, linked directly to in-

(Advertisement)

FREE USEFUL LITERATURE

Pressure Switch Selection Chart provides an easy method of finding a pressure switch for your specific application. This tabulation helps you define your requirements and saves you time in finding the correct switch for your job.

Check number M3 on the coupon below

Piston Pressure Switch bulletin describes in detail the entire service range from 15 to 3000 P.S.I. (7000 P.S.I. proof pressure). Belongs on Production Equipment, where millions of cycles are expected, and on Original Equipment, where flexibility and price are vital factors.

Check number 9612 on the coupon below.

Bourdon Tube Switches for pressures to 12000 P.S.I., single setting, housed models and skeleton models are covered in detail in these pages.

Check number 312 on the coupon below.

Diaphragm switches for vacuum and pressures to 120 P.S.I., single setting, are fully described and illustrated in this bulletin, complete with tabulation of Adjustable Ranges and Actuation Values.

Check number 420 on the coupon below.

The "Shear-Seal" Principle is a revolutionary twentieth century advancement in valving extreme pressures as well as low pressures and vacuum. The only known method to achieve leakproof closure and maintain or improve sealing qualities with use. This patented principle is illustrated and discussed in a comprehensive bulletin.

Check number BV-2 on the coupon below.

Solenoid "Shear-Seal" Valve Catalog gives complete information on line of shut-off, diverter, 3-way and 4-way selector, and 3 position selector valves for Air, Water, and Oil Service to 3000 P.S.I.

Check number 1B-2 on coupon below.

Solenoid Air Valves, the famous Crescent 3-way and 4-way valves, are catalogued with complete technical description in this eight page brochure. Where long service without valve maintenance or solenoid trouble is essential, these valves have become standard.

Check number 3C1 on the coupon below.

New 20 page catalog includes all basic information on Barksdale Manual Shear-Seal valves, Solenoid Shear-Seal valves, Meletron Pressure Switches, and Crescent Air Valves.

Check number 3G on coupon below.

Barksdale Valves

5125 Alcoa Ave., L. A. 58, Calif.

M3 ☐ 9612 ☐ 312 ☐ 420 ☐

BV-2 ☐ 1B-2 ☐ 3C-1 ☐ 3G ☐

Name ..... Title .....

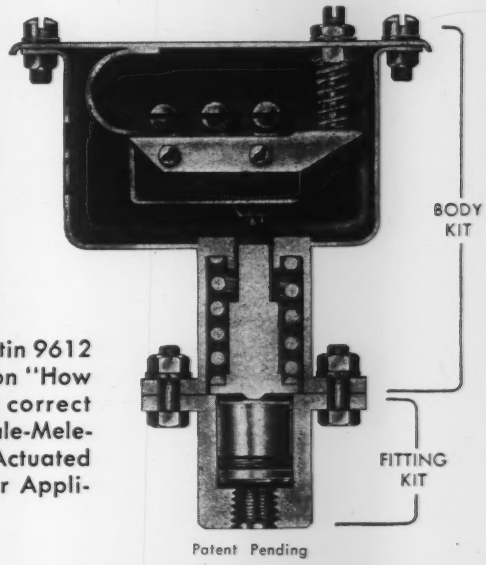
Company .....

Address .....

City ..... Zone.... State.....

MODEL 9612 PRESSURE SWITCH

It belongs where **millions of cycles** are expected, on production equipment, where service troubles are taboo. The **original equipment manufacturer** can profit by these additional advantages: **Extreme flexibility** — the same body kit converts to an infinite number of service conditions by simply changing fitting kits. **High proof pressure** even at low settings — protection against surge damage. **No unwanted actuation** from vibration or harmless line surges. Switch **may be mounted in any position** — no levelling or balancing required. **Mounting bracket adjustable** up and down and 360° around the neck of the switch. Tamperproof external adjustment. All this and more at a **low price,** due to production savings **without sacrifice of quality.**

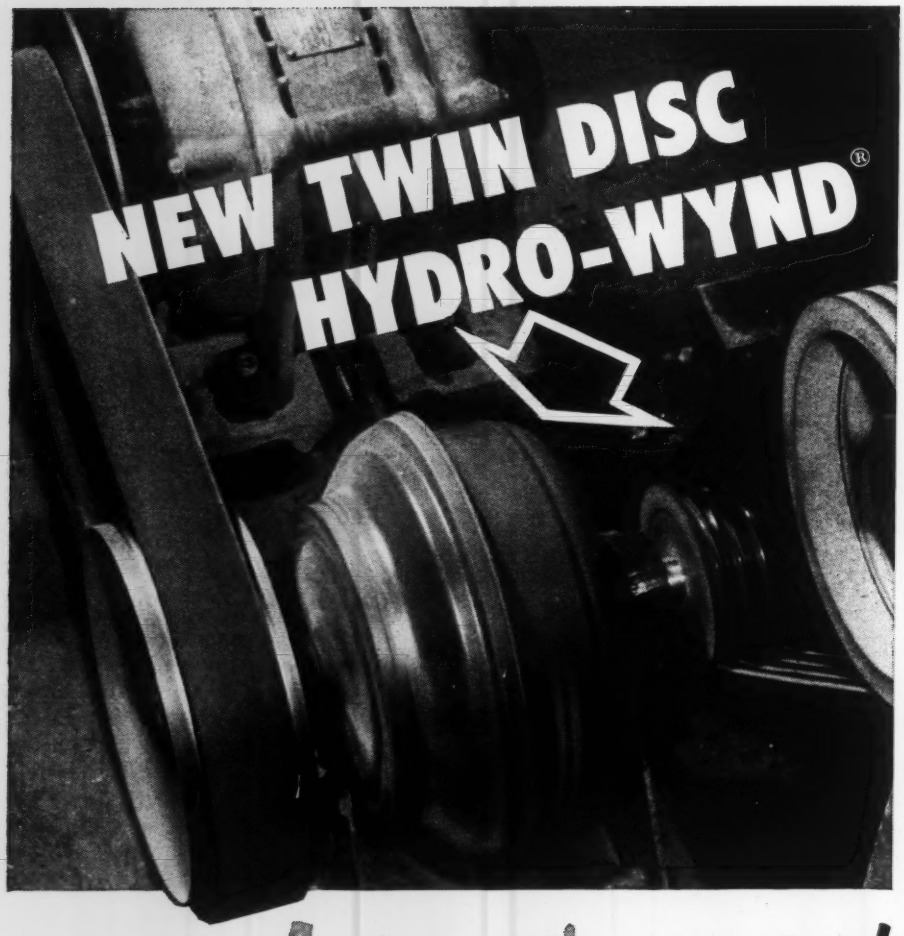


Patent Pending

Write for bulletin 9612 and the chart on "How to select the correct model Barksdale-Meletron Pressure Actuated Switch for your Application."

BARKSDALE VALVES

5125 Alcoa Avenue, Los Angeles 58, Calif.



Automatic control

for winding and tensioning, at low initial cost — without unnecessary bulk or expensive maintenance

Now available in improved design*, and in larger capacity to extend the line, the new Twin Disc Model 12.2 and 8.4 HYDRO-WYND provides a *more effective, more economical answer to automatic winding and tensioning control.*

Extremely compact — easy to install—either the 12.2 or 8.4 HYDRO-WYND combines a fluid coupling with a planetary gear set. Pre-determined tensions—once set—are maintained automatically, regardless of variations in the load demand . . . and with no further adjustments required. The result . . . *higher output per day . . . improved product quality . . .* fewer man hours required.

For complete information on the new HYDRO-WYND, call your Authorized Twin Disc Hydraulic Dealer—or write Dept. DS, Racine, Wisconsin.

*New HYDRO-WYND design features include rearrangement of gear train, better bearing spacing, and new carbon-against-steel spring-loaded seal.

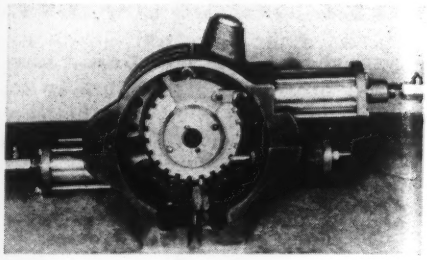
TWIN DISC
CLUTCHES AND HYDRAULIC DRIVES
REG. U.S. PAT. OFF.

TWIN DISC

TWIN DISC CLUTCH COMPANY, Racine, Wisconsin • HYDRAULIC DIVISION, Rockford, Illinois

Branches or Sales Engineering Offices: Cleveland • Dallas • Detroit • Los Angeles • Newark • New Orleans • Seattle • Tulsa

New Parts



dexing mechanism. Piston is self-contained and works independently of actuating fluid. All indexers can be operated either pneumatically or hydraulically and used in vertical or horizontal position. Standard 24-position index plate permits indexing range of 4, 6, 8, 12 and 24 positions. Made by **Erickson Tool Co.**, 2309 Hamilton Ave., Cleveland 14, O.

For more data circle MD-92, Page 223

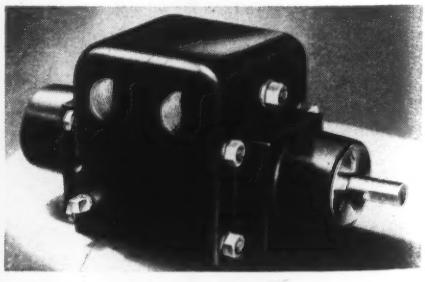
Heat Resistant Paints

Now available in metallic red and blue in addition to standard aluminum and gold, Heat-Rem high heat resistant paints withstand temperatures up to 1700 F without blistering or flaking. They are compounded from aluminum flakes in a silicone base, can be applied by brush or spray, and air dry in about 30 minutes. Coating resists rust and corrosion from mild acids, alkalies and industrial fumes. Made by **Speco Inc.**, 7308 Associate Ave., Cleveland 9, O.

For more data circle MD-93, Page 223

Corrosion Resistant Pump

Suitable for corrosive fluids with capacities up to 10 gpm and 100 psi for sustained service, Rubberchem pump has precision molded synthetic rubber casings. Sturdy



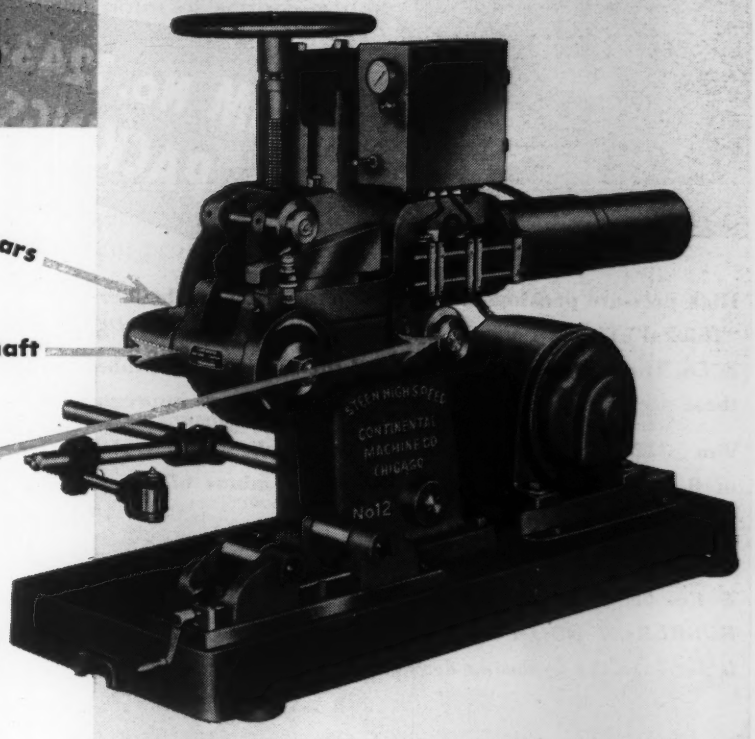
Another Bearing Problem Solved . . .

by Installing

ORANGE
Cage Type
NEEDLE BEARINGS

Eliminate extreme wear and overheating of gears and shafts in

CONTINENTAL No. 12 STEEN
High-speed, Air-operated Pipe and Tube Cut-off Machines



The success of Orange Cage Type Needle Bearings in this tough application, like so many others, is the result of

- **High load capacity in small space**

PLUS

- **Long-life operation because rollers are cage-retained—can not skew**

With the cage assuring constant alignment of rollers, Orange Cage Type Needle Bearings are true running in any position—vertical, horizontal, tilted or on overhung mountings. They are less affected by misaligned mountings or uneven loading. Extremely quiet, smooth running.

Get these advantages of the Orange cage design for your next needle bearing installations. Sizes from ½" to 8" shaft dia., interchangeable with standard heavy-duty needle bearings. Write for Engineering Data Folder.

Finding bearings that could meet space limitations, yet stand up under heavy conditions of cutting pipe and tube up to 12¾" O. D. and ⅝" wall, was a troublesome problem.

Finally, an installation using Orange Cage Type Needle Bearings proved so successful, that all drive shafts, cutter shafts and idler gears are now standardized on Orange bearings. The Continental Machine Co., Chicago, Ill., reports not a single complaint after one and a half years' continuous service.

ORANGE

ORANGE ROLLER BEARING CO., INC., 556 Main Street, Orange, N. J.

Thiokol®

LIQUID POLYMER

Combines the

TOUGHNESS OF LEATHER

with the

RESILIENCE OF RUBBER

in VIM No. 1243-3 PACKINGS

High pressure packings made from mineral-tanned leather impregnated with "Thiokol" Liquid Polymer have recently been developed by E. F. Houghton & Co. The toughness of leather and the resilience of rubber are combined in these packings by a process that insures thorough impregnation.

Vim #1243-3 packings provide extremely tight seals under pressures of 0 to 15,000 psi and temperatures of minus 65° to +200°F. They are suitable for oil and pneumatic applications.

"Thiokol" Liquid Polymer was chosen as the impregnant by E. F. Houghton & Co. because it is A SOLVENTLESS LIQUID THAT CONVERTS TO A RUBBER AT ROOM TEMPERATURE WITHOUT SHRINKAGE. On curing, it develops the following desirable properties:

- EXTREME OIL AND SOLVENT RESISTANCE
- IMPERMEABILITY TO GASES AND MOISTURE
- TOUGHNESS AND RESILIENCE
- EXCELLENT AGING CHARACTERISTICS
- BROAD OPERATING TEMPERATURE RANGE
- HIGH BOND STRENGTH

Because of its unusual properties, "Thiokol" Liquid Polymer has been selected as the elastomer for many other applications. It builds superior performance in sealers, potting and casting compounds, and adhesives. "Thiokol" Liquid Polymer may well do the same in your product or process. Write for technical information and samples.

The Thiokol Chemical Corporation supplies "Thiokol" Liquid Polymer only as a raw material. We will gladly indicate sources of supply of finished products to end-users.

Thiokol Chemical Corporation

784 NORTH CLINTON AVENUE • TRENTON 7, NEW JERSEY

In Canada: Naugatuck Chemicals Division, Dominion Rubber Company, Elmira, Ontario

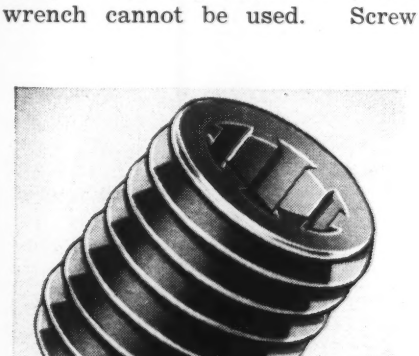
New Parts

age-cured and stress relieved, pump is self-priming and has good suction lift and linear flow. Internal parts are available in type 316 stainless steel or Monel. Made by **Eco Engineering Co.**, 12 New York Ave., Newark, N. J.

For more data circle MD-94, Page 223

Fluted Setscrews

Fluted socket Setko setscrews save production line assembly time, since the screw stays on the key, while inserting or starting in a tapped hole. They are also tamper-resistant, since a standard wrench cannot be used. Screw



can be tightened and loosened repeatedly without distortion and will not split or round out. Because this strength results from key design rather than material, they can be supplied in small sizes for small precision products. Both Zip-Grip self-locking and conventional type setscrews are available with fluted sockets. Made by **Set Screw & Mfg. Co.**, 28 Main St., Bartlett, Ill.

For more data circle MD-95, Page 223

Toggle Switch

Miniature double-pole, double-throw toggle switch is rated 10 amp at 250 v and is sealed in a bushing for panel mounting by means of a bonded silicone rubber diaphragm. Switch measures 0.625 x 0.407 x 1.140 in. A rubber O-ring is used for static seal against the chassis or panel. In its two-

Harnessing hydraulic power with

Eastman
HYDRAULIC HOSE ASSEMBLIES

Harnessing hydraulic power has been the specialty of Eastman engineers for over twenty years.

Delivering maximum power to the point of action—without the former transmission loss through other mechanical methods—has improved the mobility and efficiency of modern machinery and equipment in every field.

The amazingly compact power unit on the Sherman Power Digger below is a dramatic example of the space saving efficiency and economy of modern hydraulic engineering.

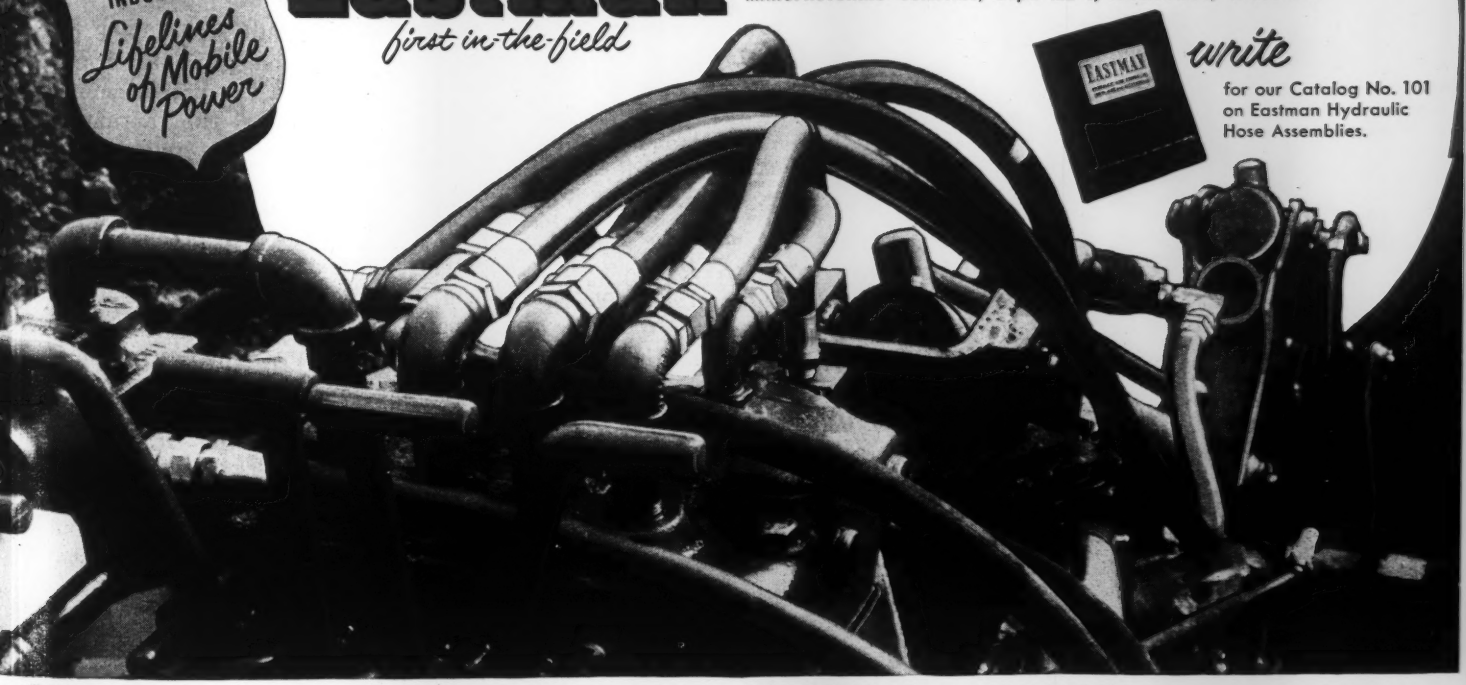
Eastman, *First in the Field* of Hydraulic Hose Assemblies, is proud to have its equipment used on the four prominent products presented below.

If you wish to obtain the fullest benefits of modern hydraulic power application and improve your competitive position in your field—the door to the *Eastman Engineering Department* is always open!

SAFEGUARDING INDUSTRY'S *Lifelines of Mobile Power*

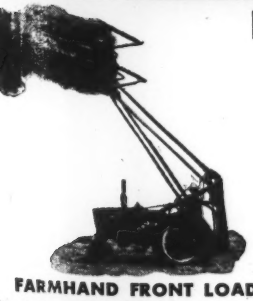
Eastman MANUFACTURING COMPANY, Dept. MD-4, MANITOWOC, WISCONSIN

first in the field

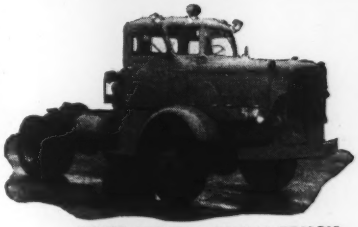


write for our Catalog No. 101 on Eastman Hydraulic Hose Assemblies.

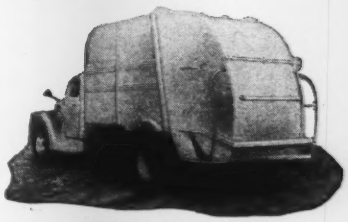
EASTMAN HYDRAULIC HOSE ASSEMBLIES AT WORK...



FARMHAND FRONT LOADER
Made by the Farmhand Co., makers of tractor end loaders, equipped with Eastman Hydraulic Hose Assemblies.



FOUR WHEEL DRIVE TRUCK
Made by the Four Wheel Drive Auto Co., "Power-Steering" through Eastman Hydraulic Hose Assemblies.



LEACH PACKMASTER
Sold by The Elgin Corporation. Power delivered to the packing unit through Eastman Hydraulic Hose Assemblies.

SHERMAN POWER DIGGER
Developed by Sherman Products, Inc., and the Wain Roy Corporation. Eastman equipped, as shown above.

SKINNER EXPLOSION-PROOF

stainless steel solenoid valves

Underwriters' Approved For Class 1, Group D, Hazardous Locations

X5 SERIES

Extremely flexible design makes the small Skinner X5 Series the *most versatile explosion-proof valve on the market!*

X5 Series Valves are inexpensive, yet built to highest quality standards. Rugged, stainless steel construction, simplicity of design (only one moving part) and spring-loaded plungers with positive-sealing synthetic inserts contribute to trouble-free operation — through *millions of cycles.*

Skinner X5 Series Valves can be easily disassembled and inspected without removal from the line.

X5 Series Valves are available in a broad selection of types, voltages, pressures, flow control adjustments, port sizes and port locations.

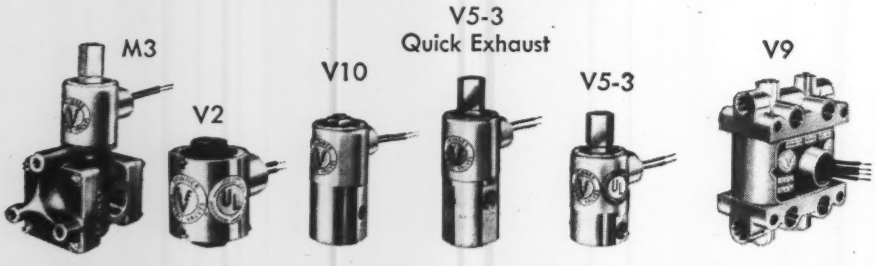
TYPE X5 SPECIFICATIONS

Type.....Two-Way and Three-Way, Normally Open, Normally Closed, and Directional Control
Pressure Range .....0-1000 p.s.i.
Orifice Diameter .....3/64" to 1/4"
Pipe Size.....1/8" or 1/4" NPT
Voltage.....All AC and DC
Power Consumption .....10 Watts Max.
Duty Cycle .....Continuous or Intermittent

Write for BULLETIN 526A

TYPICAL SKINNER VALVES

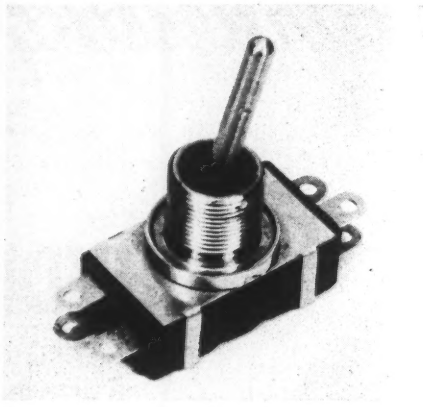
Write for information about our complete line.



SKINNER ELECTRIC VALVES — SOLENOID VALVES

THE SKINNER CHUCK COMPANY
115 EDGEWOOD AVENUE, NEW BRITAIN, CONNECTICUT

New Parts

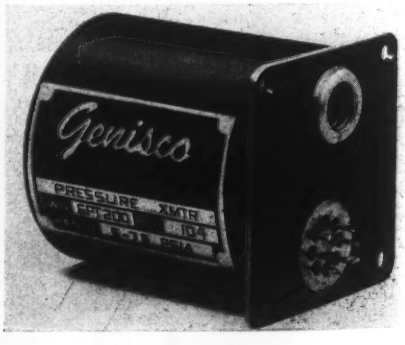


throw positions, switch has a positive locking force between contacts of 500 grams, practically eliminating separation under impact or vibration. Electric current is transferred to the contacts directly by contact springs. Made by **Krautter-Weber Tool Co.,** 69-77 Twelfth Ave., Newark 3, N. J.

For more data circle MD-96, Page 223

Pressure Transmitter

Relatively small Model GPT potentiometer type pressure transmitter, in which the potentiometer is isolated from the actuating pressure, is available in pressure ranges of 15 to 80 psi. Pressure-sensitive bellows moves the brushes of one or two precision potentiometers to vary output, which is linear with pressure. Standard potentiometer resistances are 5000 and 10,000 ohms, current rating is 7.0 ma, resolution is 0.34 per cent of full scale, and linearity is 1.0 per cent of full scale. It operates in temperature range from −50 to 90 C and withstands 40 *g* steady-state acceleration without damage, as well as 10 *g* vibration

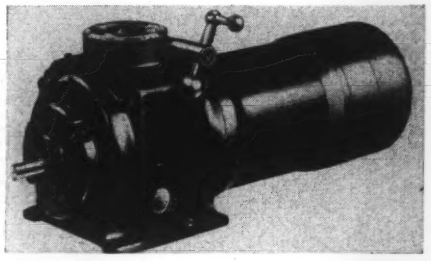


from 10 to 500 cycles per second. It is 2 in. in diameter, 2½ in. long and weighs 8 oz. Made by **Genisco. Inc.,** 2233 Federal Ave., Los Angeles 64, Calif.

For more data circle MD-97, Page 223

Variable Speed Drive

Rated at ⅛ to ¼-hp, variable speed drive is available with built-in magnetic disk brake motor in a 42-48 frame. It provides instant stops as required in indexing tables, welding positioners and tensile and compression testers.



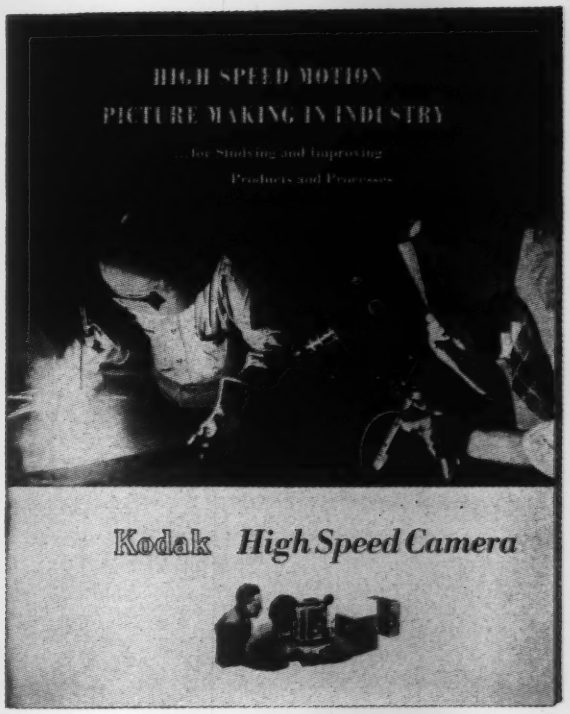
Brake has 5-in. diameter, is less than 3½ in. long and mounts directly on the end of the motor. It also has an external manual release automatic reset mechanism, friction elements which eliminate lining adjustments and replacements and a brake enclosure adaptable to both open and totally enclosed motors. Transmission is available without motor and can be had with a variety of reductions and horizontal or vertical output shafts. Micrometer or remote controls can be used. Made by **Graham Transmissions Inc.,** Menomonee Falls, Wis.

For more data circle MD-98, Page 223

Nut Locking Compound

Zorlok mastic material for tightening nuts, studs and screws is applied to bolt threads before assembly, by means of a spatula, by dipping or by squeezing direct from a tube. It dries in 72 hours at room temperature or in ½-hour at 350 F. Thread is completely sealed and seizing is controlled. Material is

(*Continued on Page* 252)



This new booklet

shows how you can use HIGH SPEED MOVIES to study and improve products and processes

Mechanical motions, in slices of time as thin as 1/16,000 of a second, are photographed in sequence. A hundred feet of film spans a second and a half or so. Edge marks on the film can time each picture. A corresponding oscillograph trace can be superimposed. Thus are revealed mechanical "bugs" hard to flush out in any other way.

That is why high speed movies are such an important testing and research tool throughout industry. This new booklet tells how it's done. It shows how leading companies use it to solve problems involving action too fast to see. It gives details on how the high speed camera works, how it can be applied to particular problems, and what you can find out about your product from the movies it makes.

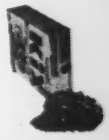
We'd be pleased to send you a copy of this informative booklet with our compliments. Just write to:

EASTMAN KODAK COMPANY
Industrial Photographic Division
Rochester 4, N. Y.

With a Kodak High Speed Camera and standard 16mm projector, you can slow action as much as 200 times. Taking up to 3200 frames per second, it has a speed range suited for most industrial applications. Easy to use, it has helped

Parker strike a hotter spark

John Deere build a better beet harvester



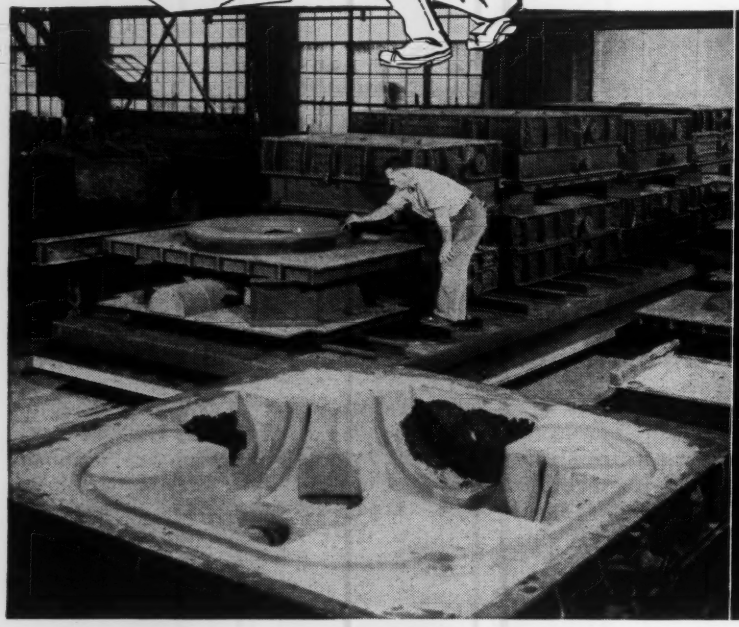
General Mills improve a puffing gun

Champion Paper and Fiber make finer papers

the Kodak HIGH SPEED Camera

Kodak

These are the working with the to make your



AT LEBANON there are electric furnaces capable of melting up to 8500 pounds—induction furnaces with 2000-pound maximum capacities. Here, too, special Swiss* molding and production processes are combined with the finest in American methods and procedures. The CENTRI-DIE* process for making centrifugal castings in permanent molds—a process *introduced* in this country by Lebanon—provides the highest quality castings for difficult corrosion and heat resisting services. Pattern-making, core-making, heat-treating, finishing and cleaning complete the picture of equipment that produces Lebanon CIRCLE Ⓛ castings.

But equipment is not the whole story. Lebanon

CIRCLE L

CARBON, SPECIAL ALLOY AND STAINLESS STEEL CASTINGS

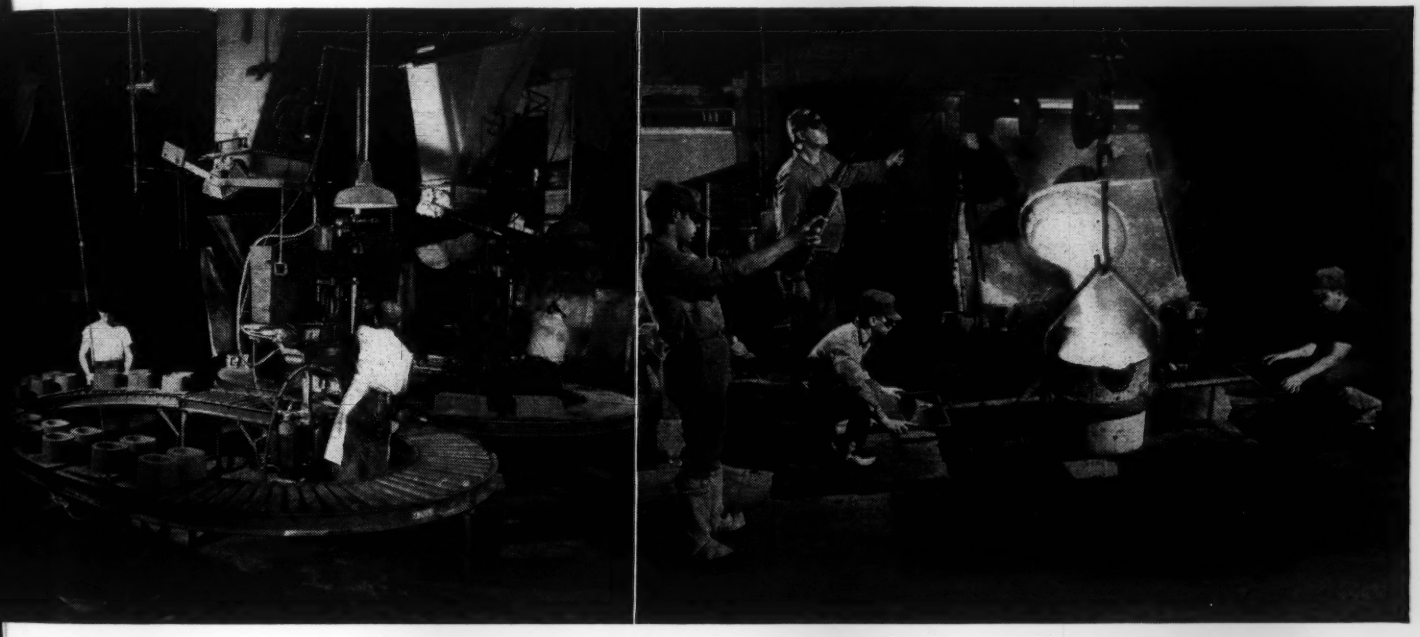
LEBANON STEEL FOUNDRY

LEBANON—PENNSYLVANIA

right men

right equipment

STEEL CASTINGS



foundrymen add immeasurably to the high quality of CIRCLE Ⓛ engineered products. These workers are craftsmen in every sense of the word, men trained and highly skilled, men dedicated to doing all they can to make your castings *right.*

If the pictures on these pages could talk they'd say, "Here's where equipment and craftsmen make Lebanon CIRCLE Ⓛ castings to a *high standard*—not to a price!" We believe sincerely that there is no economy in buying just by price . . . it is far better to buy the best product at a reasonable cost.

LEBANON STEEL FOUNDRY • LEBANON, PA.

*Special processes acquired from George Fischer, Ltd., of Switzerland. Lebanon Steel Foundry was also the original licensee for the centrifugal casting process developed by Firth-Vickers Stainless Steels, Ltd., Sheffield, England.

Lebanon Steel Foundry
64 Lehman St., Lebanon, Pa.

Please send me one of your new Lebanon Slide Charts.

Name.....

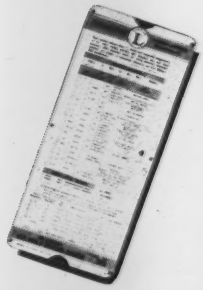
Company.....

Address.....

.....

Get *your* Lebanon Slide Chart *now* . . .

This handy slide chart gives you the nominal analyses, various designations, minimum mechanical properties and heat treatment for 19 Lebanon carbon and low alloy grades and 17 stainless and corrosion-resistant grades. Send coupon today . . .



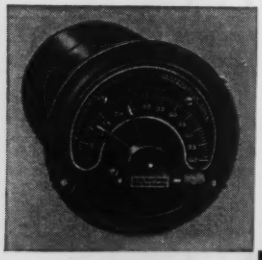
THREAD PRECISION AND UNIFORMITY INSURED WITH CRAMER TIME CONTROL

The threading accuracy of this Steinle Roll Threading Machine is directly related to the highly dependable Cramer Timers which govern the roll slide movements. This carefully predetermined slide travel must be extremely accurate in order to insure thread precision and uniformity.

The Cramer TE Timer, at left, controls the time of dwell of the roll slide in its forward position, while the one at right dictates the exact loading interval. A simple adjustment of either timer permits slow-down or speed-up of the action. Cramer-controlled threading operations on the Steinle machine have been speeded to 40 complete cycles per minute without sacrifice of thread accuracy. There has never been a report of timer failure.

The Steinle Machine is widely used by aircraft manufacturers and others who require extremely accurate threads. Cramer Timers are specified as original equipment for these machines due to their unusually high standards of accuracy and dependability.

If you have a time control problem, Cramer can help you. Write for complete information or technical advice.



The overall accuracy of the Type TE (inclusive of setting) is within 2%, with repeat accuracy within ½ of 1%. The unit is Underwriters' Laboratories listed for use in industrial control equipment.

A "look inside" will show you why you can always depend on Cramer for outstanding performance. Check the "inside" facts, today.

SPECIALISTS IN TIME CONTROL

Cramer TIMING DEVICES

the R. W. CRAMER CO., INC.

BOX 6, CENTERBROOK, CONNECTICUT

2CR54R

New Parts

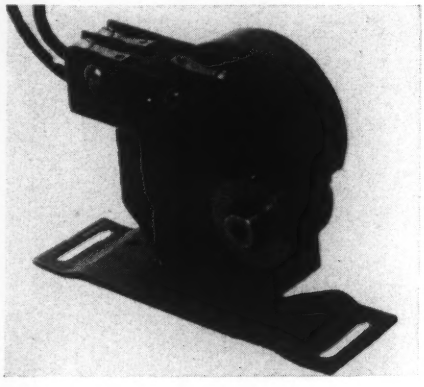
(*Continued from Page 249*)

noncorrosive, nonoxidizing and prevents thread rust. It resists oil, grease, acids, alkalies and other corroding media. Nut and bolt can be reused. Elimination of the use of lock washers and special locknuts is claimed. Made by **Presstite Engineering Co.**, 3798 Chouteau Ave., St. Louis 10, Mo.

For more data circle MD-99, Page 223

Pulse Timer

Arrangement of cams in this long range pulse timer provides accurate momentary pulses, even when widely spaced in regard to time. Pulses will occur regularly

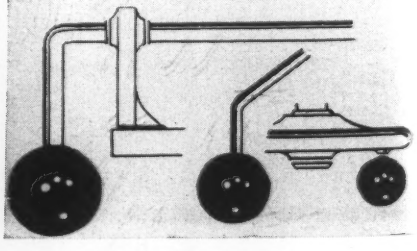


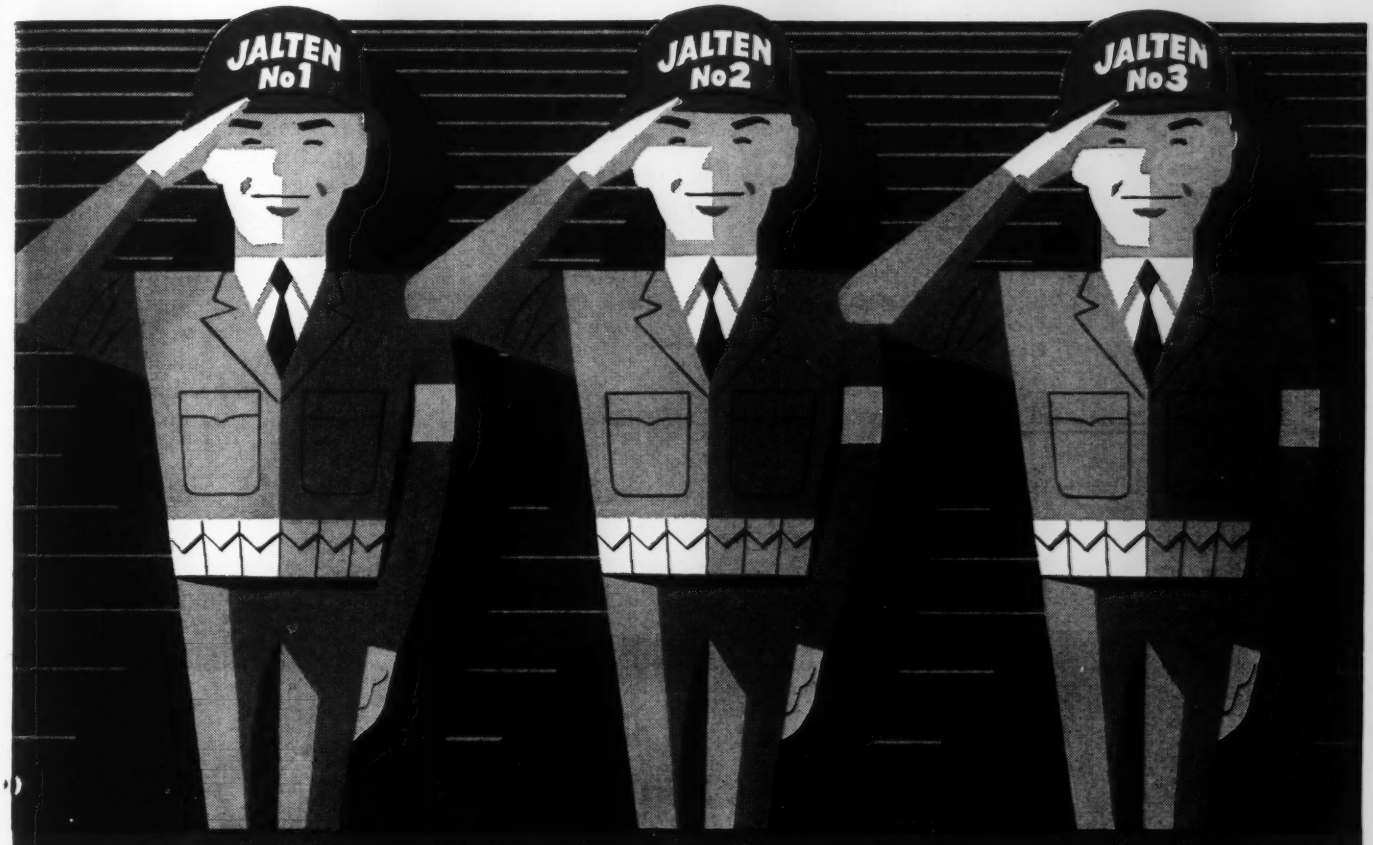
at factory preset intervals. Their frequency can be altered, by changing gears, from one pulse every 15 seconds to one pulse per week. Made by **Hagen Mfg. Co.**, 202 Twentieth St., Moline, Ill.

For more data circle MD-100, Page 223

Plastic Knobs

Plastic ball lever knobs are available measuring 1, 1⅝ and 2-in. OD. The 2-in. size is available with a ¼ or ⅝-in. tapped steel insert, th





Give your order...

THEY'RE ALL JALTEN!

J&L's New JALTEN series enables you to select low-alloy, high-strength steel in the following combinations of advantages:

JALTEN No. 1 — High strength, good formability and fabricating —good resistance to low temperature impact.

JALTEN No. 2 — High strength, moderate forming—improved resistance to atmospheric corrosion.

JALTEN No. 3 — High strength—improved resistance to abrasion.

Remember to specify JALTEN High Tensile Steel for

- **HIGH STRENGTH • RESISTANCE TO CORROSION**
- **GOOD FORMABILITY • RESISTANCE TO ABRASION**

J&L STEEL

Jones & Laughlin
STEEL CORPORATION — *Pittsburgh*

The data you want is in this book:

- Chemical Properties of Jalten
- Mechanical Properties of Jalten
- Jalten Equivalents
- Jalten Application Data

Jones & Laughlin Steel Corporation
Dept. 410, 3 Gateway Center, Pittsburgh 30, Pa.

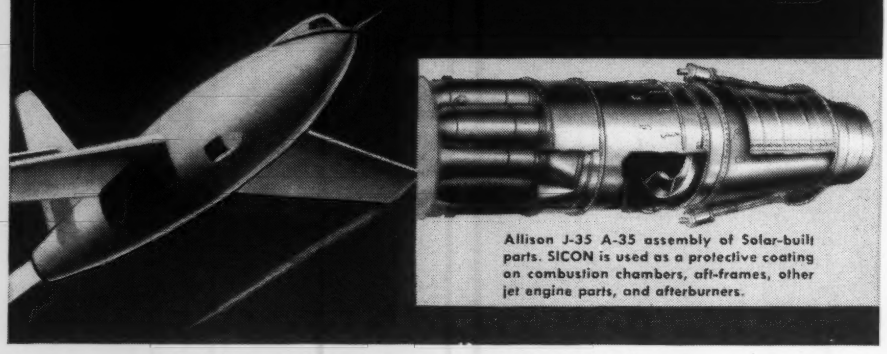
Please forward a copy of your booklet, Jalten low-alloy, high-strength steel.

Name_____

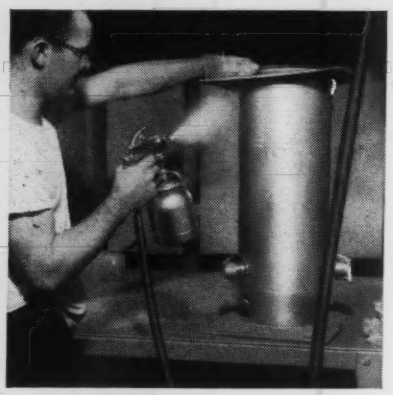
Company_____

Address_____

PROTECTING JET ENGINE PARTS with Sicon Silicone Coating



Allison J-35 A-35 assembly of Solar-built parts. SICON is used as a protective coating on combustion chambers, aft-frames, other jet engine parts, and afterburners.



Operator masks end of combustion chamber with simple cardboard shields as he applies SICON finish to resist temperatures up to 800°F.

This J-35 afterburner shroud assembly has been masked at critical hole patterns and threaded attachments before being sprayed with SICON silicone coating.

HEAT RESISTANCE UP TO 800°F. *plus* EASY APPLICATION

An example of how SICON solves Finish Problems for Design Engineers.

Jet engine parts made by Solar Aircraft are fabricated from special aluminized steel to meet conditions of extremely high temperatures. Certain welding operations destroy the aluminized surface, and at such critical points SICON was first adopted as a touch-up finish to renew vital protection needed. SICON proved stable under searing heat tests due to its strong film adhesion and excellent heat resistance characteristics, also so easy and fast to apply that many parts are now given an all-over SICON coating.

Rigorous heat tests have proved SICON best for many other products such as automobile manifolds, exhaust pipes, furnaces, and heaters. SICON is easy to apply, by brush, spray, or dip, to any chemically clean surface; and in many cases can be either air-dried or baked.

Decorative colors for lower temperature needs—whites, beiges, tans, and other shades, all with excellent retention of color and gloss in the 550°F. range, are now available.

Write us about your problem. If a SICON formulation is indicated we will provide a sample based on color and temperature requirements.

MIDLAND Industrial Finishes Co.
EAST WATER ST., WAUKEGAN, ILLINOIS
ENAMELS · SYNTHETICS · LACQUERS · VARNISHES

Sicon

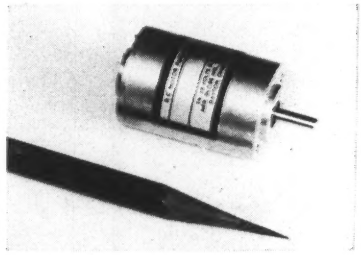
New Parts

1⅝-in. size has a tapped ⅜-in. brass insert and the 1-in. size a ¼-in. tapped hole. Used as knobs on clutches, gears and levers on machine tools, balls are good thermal insulators and provide insulation against electric shock. Chipping does not result in splintering and formation of sharp edges. Made by **Jergens Tool Specialty Co.**, 712 E. 163rd St., Cleveland 12, O.

For more data circle MD-101, Page 223

Miniature Motor

Type SS Moto-Mite is available with different windings to produce various characteristics; standard models have no-load speeds of 5000



to 22,000 rpm at 27 v. Typical motor is ⅞-in. in diameter, 1⅜ in. long, has stall torque of 1 oz-in. and no-load speed of 14,000 rpm. Shaft lengths are available up to 1 in. extension. Made by **Globe Industries Inc.**, 1784 Stanley Ave., Dayton 4, O.

For more data circle MD-102, Page 223

Anchor Locknut

Lightweight two-lug anchor locknut up to 45 per cent lighter than previous models is designed for service up to 1200 F. Designated ESNA ZA1W1200, locknut is available with base plates having plain lugs, lugs with projections for welding, or lugs with holes for riveting. Nut portion of unit is made of Columbium-stabilized 347 stainless steel, which imparts reusable locking properties. Base plate which forms the lugs for welding or riveting is made of type 321 stainless. Silver plating process is used on nuts as lubricant to prevent seizing and galling after high

Certified **BRAD FOOTE GEARS**

No increase in price!

A NEW WAY FOR YOU TO BUY GEARS

• Now you can specify by brand name the gears or assemblies you need and be sure that every desirable quality for longer life and lower service cost will be built into them. This name—*Certified* BRAD FOOTE Gears.

Certified BRAD FOOTE Gears are made according to an exclusive BRAD FOOTE formula which controls every step in the manufacturing process. It is your assurance that the gears will have long-wearing teeth and bearing areas, and tough cores that will give service equal to or better than any other gears made.

Copper Plating* permits smooth, quick run-in. It is clean and prevents rust and corrosion before gears are put in service. It's your positive identification of the best gears that money can buy. *Yet . . . you pay no more.*

The Certificate furnished with *Certified* BRAD FOOTE Gears and assemblies certifies strict adherence to specifications and the exclusive BRAD FOOTE formula. It proves that "*no one shares our responsibility.*"

**Gears over 30" diameter are protected by copper-colored water-soluble paint which need not be removed before placing in service*

Write today for descriptive literature

© BFGW, INC.

BRAD FOOTE GEAR WORKS, INC.

1309 South Cicero Avenue • Cicero 50, Illinois
BIshop 2-1070 • OLympic 2-7700

subsidiaries

AMERICAN GEAR & MFG. CO.
Phone: Lemont 920
Lemont, Illinois

PITTSBURGH GEAR COMPANY
Phone: SPaulding 1-4600
Pittsburgh 25, Pennsylvania

A NEW PLANT

A modern building designed specifically for relay manufacture is another step in the continuing effort to improve Struthers-Dunn services and maintain maximum production of high quality products at favorable prices.

A NEW LOCATION

The entire Struthers-Dunn factory and headquarter offices have been moved to a new location, approximately 15 miles Southeast of the Philadelphia-Camden Area.

NEW ADDRESS

LAMB'S ROAD • PITMAN, N. J.

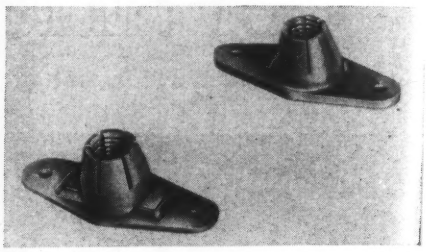
NEW TELEPHONE

PITMAN 3-7500

S-D
STRUTHERS-DUNN, INC.

STRUTHERS-DUNN
5,348 RELAY TYPES

New Parts

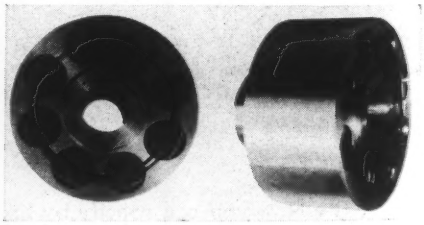


temperature service. Base and nut body are supplied welded together to facilitate handling. Illustration contrasts new nut, left, with previous design. Made by **Elastic Stop Nut Corp. of America,** 2330 Vauxhall Rd., Union, N. J.

For more data circle MD-103, Page 223

Flexible Coupling

Elastic coupling, available in ¼ to 6-in. diameter shaft sizes, uses replaceable solid Neoprene cylinders which are inserted between two shaft hubs and retained axially by lockwires. Subjected to a combination of shear and compression stresses, cylinders provide good torsional flexibility. Snubbing characteristics of this arrangement are



instrumental in isolating or damping torsional vibration. Larger sizes are suitable for couplings between internal combustion engines and driven machines. Made by **Odin Corp.,** P. O. Box 6032, Indianapolis 20, Ind.

For more data circle MD-104, Page 223

Silicone Rubber

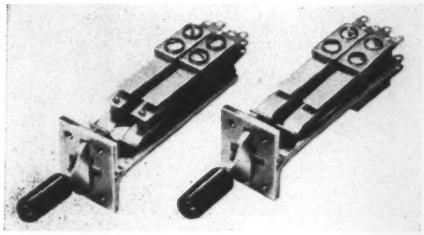
Tear strength of Super Tough silicone rubber averages 190 psi. Available in grades 15060, 15080 and 15081, the elastomer exhibits the thermal properties of silicones, with increased tear strength and

oil resistance. Uses include O-rings and gaskets, which function as seals for synthetic base oils at temperatures as high as 375 F, as well as molded ducts and connectors for hot air lines, particularly where oil mist is present. Material withstands high temperatures, pressure and vacuum and remains flexible over a range of −65 to 550 F. All grades are available in molded form. Made by Plastics Dept., **General Electric Co.**, N. 22nd St., Decatur, Ill.

For more data circle MD-105, Page 223

Telephone Type Switch

Lightweight Telever telephone type switch has T-beam frame construction. Available in various

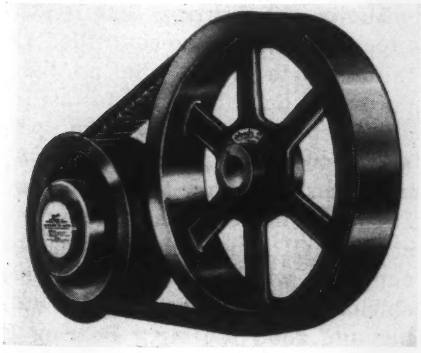


contact arrangements in two and three-position types, it measures 4¼ x 1 7/32 x 15/16-in. Lever has nylon rollers. Contact rating is 3 amp at 120 v ac noninductive load. Made by **Switchcraft Inc.**, 1328 N. Halsted St., Chicago 22, Ill.

For more data circle MD-106, Page 223

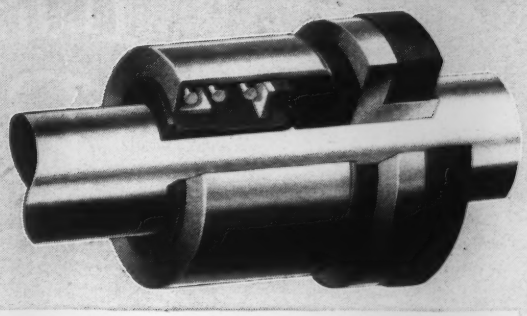
Variable Speed Sheaves

Variable speed drive is available with from 5 to 20 hp ratings and is of variable pitch sheave

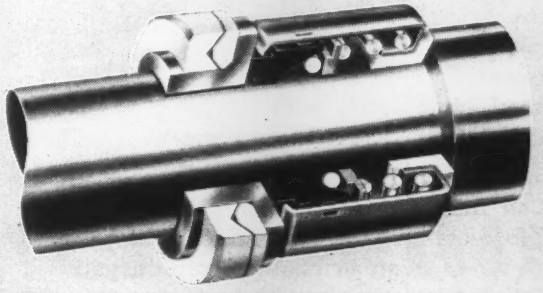


Garlock "Package" Seals
FOR ROTATING PUMP SHAFTS

Type BB-21A—Garlock Package Seal of standard construction with brass shell, brass washer, and Buna-N bellows.



	TYPE BB-21A	TYPE AA-21A
Liquids	For water, oils, alcohol, solvents (except aromatic, chlorinated and ketone types) and other liquids (except strong acids).	For very strong acids, oils, solvents (including aromatic, chlorinated and ketone types) and all other liquids.
Equipment	Rotating shafts of centrifugal pumps, process pumps, chemical pumps, agitators and similar applications.	
Sizes	For shafts from ⅜" to 3" diameters.	
Temperatures	With Buna-N bellows up to 212°; with silicone bellows up to 450° F.	Up to 450° F.
Pressures	Up to 150 p.s.i.	Up to 150 p.s.i.



Type AA-21A—Garlock Package Seal with hat-shaped "Teflon" drive ring, brass or 316 stainless steel shell and washer, "Teflon" 'O' ring, and "Teflon" two-piece vibration ring.

✓ CHECK THESE IMPORTANT FEATURES

- ☐ Occupy very small space
- ☐ Completely assembled—ready to install
- ☐ Proven performance at low cost
- ☐ Both types are dimensionally interchangeable

In both of these Package Seals, a leakless seal is provided by a positive contact between carefully lapped metal-to-carbon mating surfaces. All metal parts in both types are available in plated-brass, Ni-Resist, stainless steel with malcomized face, Garlock "B" iron, and others.

For complete details, ask your Garlock representative or write us about your sealing problems.

THE GARLOCK PACKING COMPANY
PALMYRA, NEW YORK
In Canada: The Garlock Packing Company of Canada Ltd., Toronto, Ont.
Branch Offices in Most Principal Cities

GARLOCK
PACKINGS, GASKETS, OIL SEALS,
MECHANICAL SEALS,
RUBBER EXPANSION JOINTS

The headaches caused by threaded fastenings — soft materials, corrosion, frequent use—are banished immediately with *Heli-Coil Screw Thread Inserts.**

Thousands of manufacturers have used and proved them. ***Heli-Coil*** Inserts provide much greater loading strength for your threads, make threads so perfect they will never wear, strip, seize, corrode, gall. With ***Heli-Coil*** Inserts you can use fewer, smaller, shorter fastenings and lighter, cheaper materials... this saves you space, weight and MONEY.

Check today on how and why ***Heli-Coil*** Screw Thread Inserts are the answer to the designer's prayer. Just mail the coupon for full information and samples.

***Heli-Coil* Inserts conform to official Military Standards MS-122076 (ASG) through MS-124850 (ASG) and others.**

* Reg. U. S. Pat. Off.

HELI-COIL CORPORATION
124 SHELTER ROCK LANE, DANBURY, CONN.

☐ Send samples and Bulletin 689 — Military Standard Sheets.
☐ Please have a *Heli-Coil* Thread Engineer call.
☐ Send samples and Handbook 652, a complete design manual.

NAME_____ TITLE_____
COMPANY_____
ADDRESS_____
CITY_____ ZONE____ STATE_____ 2710

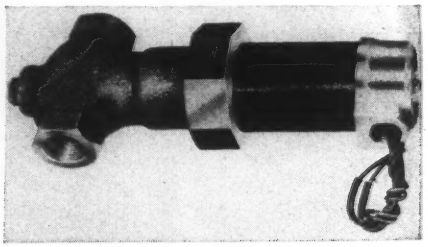
New Parts

construction. It has a single wide belt to give maximum transmission efficiency and is adjustable for sheave pitch at either end of the hub. Speeds are infinitely adjustable over a 3:1 ratio. Unit does not need lubrication and is available in four sizes. Made by **T. B. Wood's Sons Co.**, Chambersburg, Pa.

For more data circle MD-107, Page 223

Solenoid Valves

Available in sizes from ½ to 2 in., cast iron and cast steel solenoid valves have ratings ranging from 500 psi at 450 F to 1000 psi at 200 F. They handle all media normally injurious to brass or bronze but not



to ferrous metals. Stainless steel hooded pilot seat screw gives positive closing action, and design compensates for heat to prevent sticking. Teflon disks are inert to all media except hot fluorine, and Neoprene O-rings seal joints and prevent leakage. Removable inserts are used throughout the complete size range. Made by **Atkomatic Valve Co.**, Dept. 262, 545 Abbott St., Indianapolis 25, Ind.

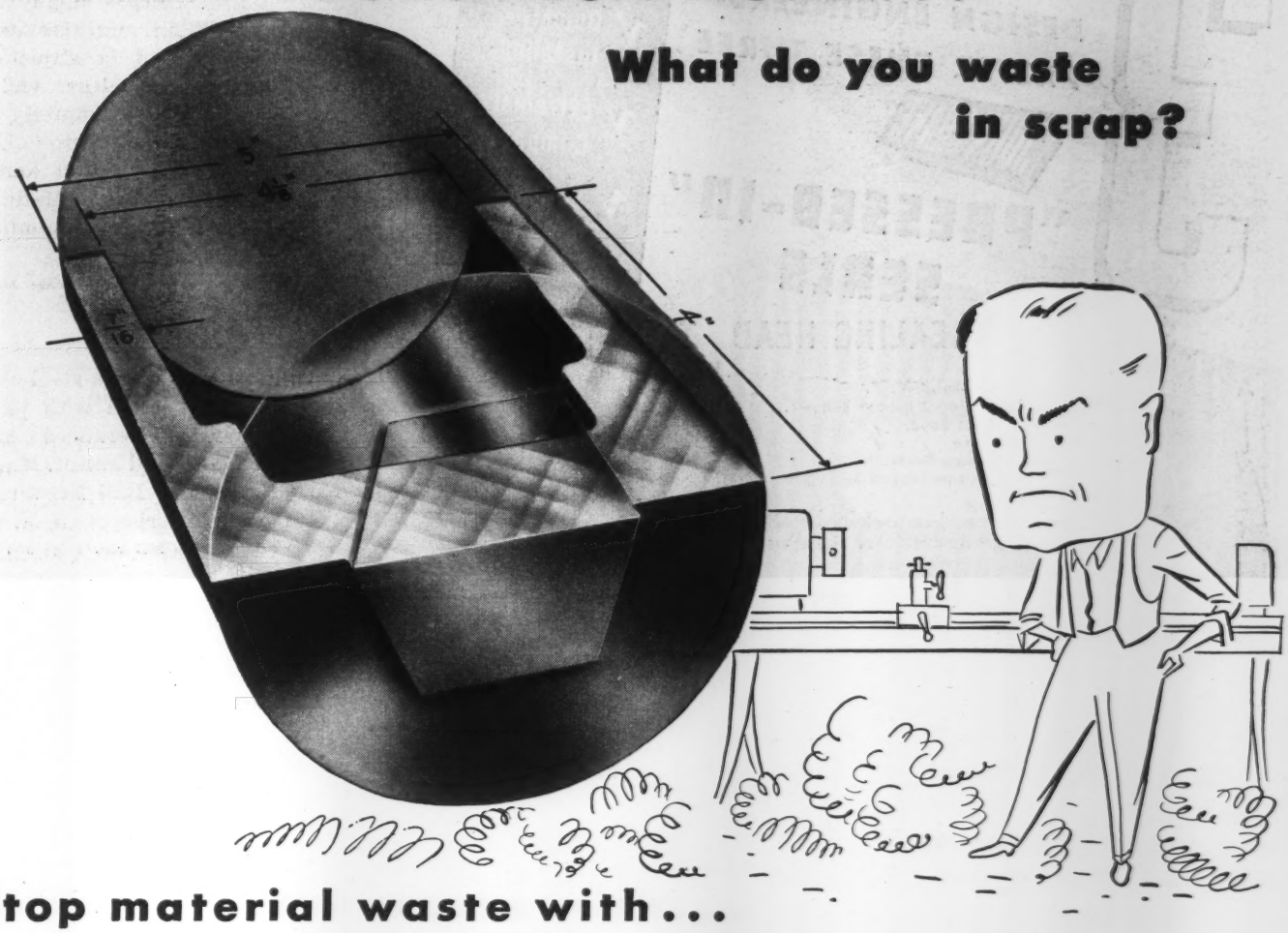
For more data circle MD-108, Page 223

Instrument Bearing

Micro R2 bearing has ribbon type, balanced, cone-controlled retainer which cannot wind up, hang up or fall out. Starting torque requirements are low and high operating speeds are possible. Bearing has been tested up to 90,000 rpm. It is available with flange and straight OD, and both styles can be supplied with one or two side shields, simplified housings, mounting and solid seating. Bearing is

Mr. Production Head...

What do you waste in scrap?



Stop material waste with...

IMPACT FORGING
FROM
HIGH STRENGTH ALUMINUM ALLOYS

Think of the metal waste if the cylinder cap shown above were machined! The turnings would represent dead loss—expensive material and machining time.

By employing Hunter Douglas Impact Forging, the cylinder cap shown was produced on a mass production basis. The contoured grain flow of a forging gave great strength to resist high bursting pressures. Metal waste was practically non-existent, machining time was reduced to minor finishing operations with the resultant saving in production time.

Cold Impact Forging is a mass production technique perfected by Hunter Douglas and offering the strength and grain flow of a forging with the tolerance and precision of an extrusion. In most cases, a part is forged to final print, in every case machining operations are reduced to a minimum. For example, note in the illustration that the hexagon nut and cylinder cap were forged *in a single operation.*

Hunter Douglas has produced millions of high strength aluminum alloy impact forgings at great savings in time, cost, and material. If you are designing or producing a part calling for close tolerances and high strength, in quantities of from one thousand to one million per month, find out how Hunter Douglas Impact Forging can improve your production picture.

write for free brochure on your company letterhead

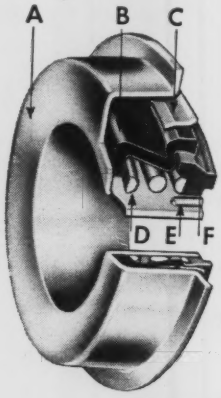
HUNTER DOUGLAS CORPORATION

DEPT. 12 • RIVERSIDE, CALIFORNIA • TELEPHONE RIVERSIDE 7091

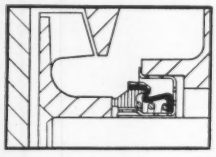
3 REASONS WHY DESIGN ENGINEERS PREFER THESE THREE JOHN CRANE "PRESSED-IN" SEALS

✓ Quickly Installed
✓ Extremely Compact
✓ Low in Cost

STATIONARY SEALING HEAD TYPE 11-A



A. Seal Retainer.
B. Synthethic Rubber Bellows.
C. Metal Band.
D. Spring.
E. Holding Dents.
F. Precision-Lapped Sealing Washer.



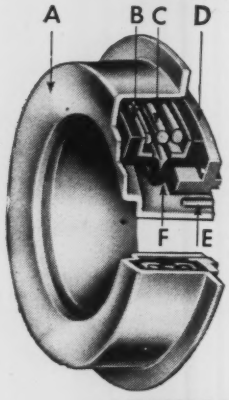
This pressed-in packaged sealing unit is designed with the spiral steel spring inside of the synthetic rubber bellows to protect it against corrosion.

The spring clamps the flange of the bellows tight against the bottom of retainer and the metal ferrule squeezes the top portion of the bellows against the "Teeplelite" washer.

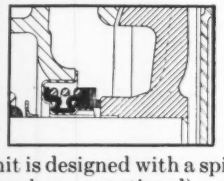
This liquid-tight seal is especially recommended for small shafts on *hot or cold water, oil, gasoline, kerosene, soapy water.*

Use this seal on: *Low Pressures* to 35 PSI
Temperatures —65°F. to +220°F.

STATIONARY SEALING HEAD TYPE 6-A



A. Seal Retainer.
B. Metal Ferrules.
C. Spring.
D. Precision-Lapped Sealing Washer.
E. Holding Dents.
F. Synthetic Rubber Bellows.

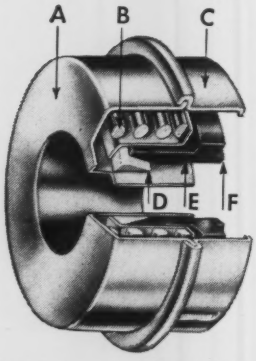


This pressed-in packaged sealing unit is designed with a spiral steel cadmium plated spring (stainless or bronze optional) assembled between two metal ferrules which clamp the flanges of the synthetic rubber bellows tightly against the retainer shell and the "Teeplelite" washer.

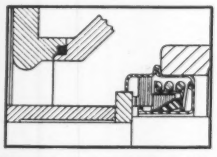
This liquid-tight seal is especially recommended for small shafts on *hot or cold water, oil, gasoline, kerosene, soapy water.*

Use this seal on: *Medium Pressures* to 75 PSI
Temperatures —65°F. to +220°F.

STATIONARY SEALING HEAD TYPE 9-A



A. Seal Retainer.
B. Spring.
C. Sleeve.
D. Wedge of Teflon.
E. Sealing Washer.
F. Precison-Lapped Face.



This pressed-in packaged sealing unit is designed to use a wedge sealing ring of Teflon*. This wedge shaped sealing ring closely fits the inner sleeve of the retainer and makes a liquid-tight contact with cone surface of carbon washer.

The result is a liquid-tight seal which is especially recommended for *hot oil, and all chemical liquids or gases, hot or cold.*

Use this seal on: *High Pressures* to 150 PSI
High Temperatures +485°F. *Low Temperatures* —120°F.

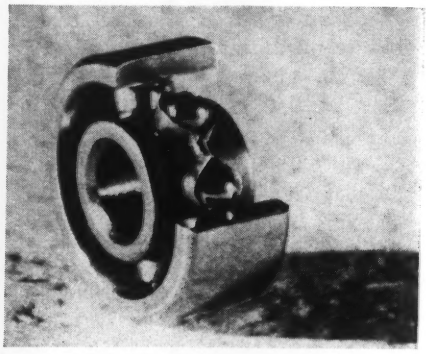
Write for fact-filled catalog. Crane Packing Company, 1825 Cuyler Ave., Chicago 13, Ill.

In Canada: Crane Packing Company, Ltd., 617 Parkdale Ave., N., Hamilton, Ont.

**DuPont trademark*

JOHN CRANE
CRANE PACKING COMPANY

New Parts

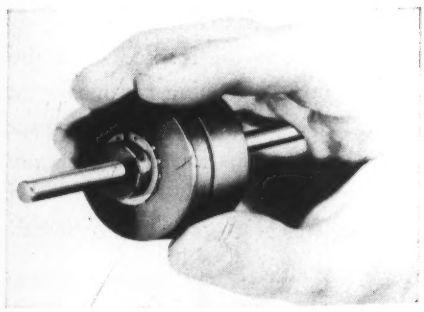


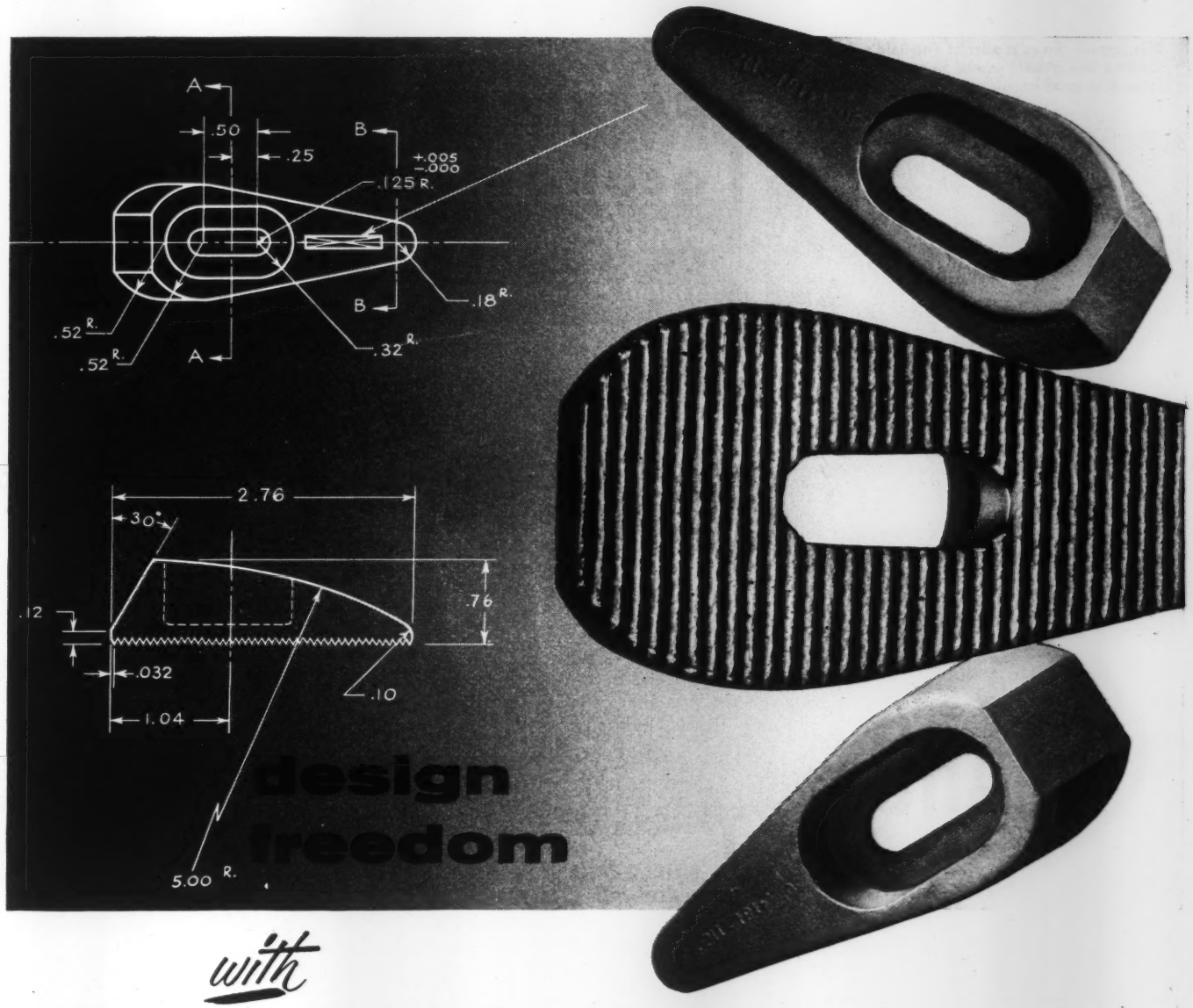
also available in stainless steel and in angular construction with phenolic retainer. Tolerances are ABEC5 to ABEC7 and better. Made by **New Hampshire Ball Bearings, Inc.,** Grove St., Peterborough, N. H.

For more data circle MD-109, Page 223

Brakes and Clutches

Compact electric brakes, clutches and clutch-couplings are designed for fast accurate control of low-torque drives. High-speed engagement and release, coupled with torque ratings from 8 to 240 lb-in., make units adaptable to starting, stopping, indexing, rapid cycling, synchronizing, torque limiting, indexing and jogging and single revolution cycling applications. Rated speeds are 10,000, 7200 and 4500 rpm. Pushbutton or automatic operation is possible with limit switches, relays, electric eyes and other electric controls. Units operate on 6 to 15-w at 6, 12, 28, 40 and 90 v dc and require from 1⅜ to 2 9/32-in. axial space for mounting. Precision rotary and lineal positioning of machinery are easily obtained, voltage being adjusted by rheostats giving a wide selection of acceleration and deceleration rates. Automatic take-up for friction sur-





with

CRUCIBLE ACCUMET PRECISION INVESTMENT CASTINGS...

Here's another good example of how Accumet Precision Investment Castings help put an end to design problems.

To machine the curved and tapered surfaces, elongated hole and counterbore, and serrations on this AISI 4140 alloy steel aircraft part, would have been too costly to be practical. But the parts were quickly and economically produced by investment casting.

More and more parts are being *designed* specifically for the investment casting process. And there are good reasons why. Crucible Accumet Precision Castings allow the greatest freedom of design. Intricately shaped parts can be made of any grade of steel, including high-alloys, in large quantities and at low cost.

It will pay you to let your local Crucible representative give you the whole story of how Accumet Precision Castings can help you produce a better product at lower cost.

CRUCIBLE first name in special purpose steels

54 years of Fine steelmaking

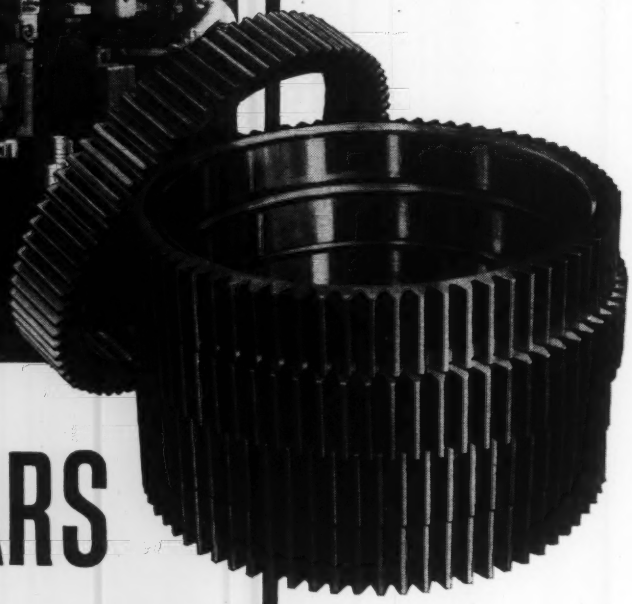
ACCUMET PRECISION CASTINGS

CRUCIBLE STEEL COMPANY OF AMERICA, GENERAL SALES OFFICES, OLIVER BUILDING, PITTSBURGH, PA.

REX HIGH SPEED • TOOL • REZISTAL STAINLESS • ALLOY • MAX-EL • SPECIAL PURPOSE STEELS

● This picture shows a part of Fairfield's Spur Gear Cutting Department where finest, new equipment is used to produce gears up to 1½ pitch, 36" dia.

accuracy
economy
capacity



GEARS
by Fairfield

AT FAIRFIELD, you get the benefit of mass production ECONOMY, combined with every modern facility for manufacturing FINE GEARS!

Here "under one roof" is everything needed to meet your most exacting gear requirements — metallurgical department, batteries of the most modern machines, testing laboratories, complete heat-treating facilities — all operated by skilled craftsmen working under expert engineering supervision.

Get acquainted with the Manufacturing Service Fairfield offers to makers of agricultural implements, road building machinery, machine tools, engines, trucks, tractors, and all kinds of powered equipment. *Your inquiry will receive prompt attention — ask for interesting, illustrated bulletin.*

FINE GEARS
MADE TO ORDER

SPUR GEARS — Straight, helical, and internal. Sizes from 16 pitch, 1½" dia., to 1½ pitch, 36" dia.

HERRINGBONE—(*Fellows Type*). Sizes from 1½" to 15".

SPIRAL BEVEL — Sizes from 16 pitch, 1½" dia., to 1½ pitch, 28" dia.

STRAIGHT BEVEL—Sizes from 16 pitch, 1½" dia., to 1½ pitch, 28" dia.

HYPOID—Sizes from 1½" to 28" dia.

ZEROL — Sizes from 16 pitch, 1½" dia., to 1½ pitch, 21" dia.

WORMS AND WORM GEARS—Worms to 7" dia. Worm gears to 36" dia.

SPLINED SHAFTS — Lengths to 52". Diameters from 1" to 6".

DIFFERENTIALS — 10,000 to 300,000 inch pounds capacity.

Note: All of the sizes above are approximate.

FAIRFIELD
MANUFACTURING CO.
2307 South Concord Road • Lafayette, Indiana

New Parts

face wear is provided. Made by **Warner Electric Brake & Clutch Co.**, Beloit, Wis.

For more data circle MD-110, Page 223

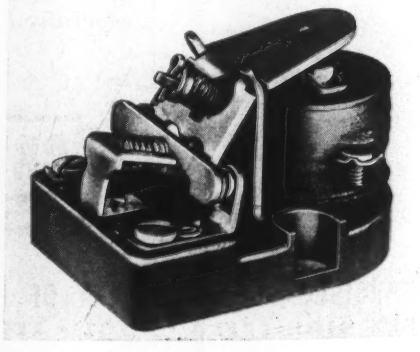
Felt Sealing Tape

Although very tacky, the adhesive used on this sealing tape does not stick to the felt itself; no separator backing is used in rolled-up tape. Felt is treated to provide increased tensile strength, abrasion resistance, and moisture and fungus resistant characteristics. Kling Felt 300 is available with No. 302 pressure sensitive adhesive or No. 313 solvent activated adhesive, the latter for use on cold or damp metal or where a strong diagonal pressure might tend to cause the tape to slide. Made by **Products Research Co.**, 3126 Los Feliz Blvd., Los Angeles 39, Calif.

For more data circle MD-111, Page 223

Magnetic Relay

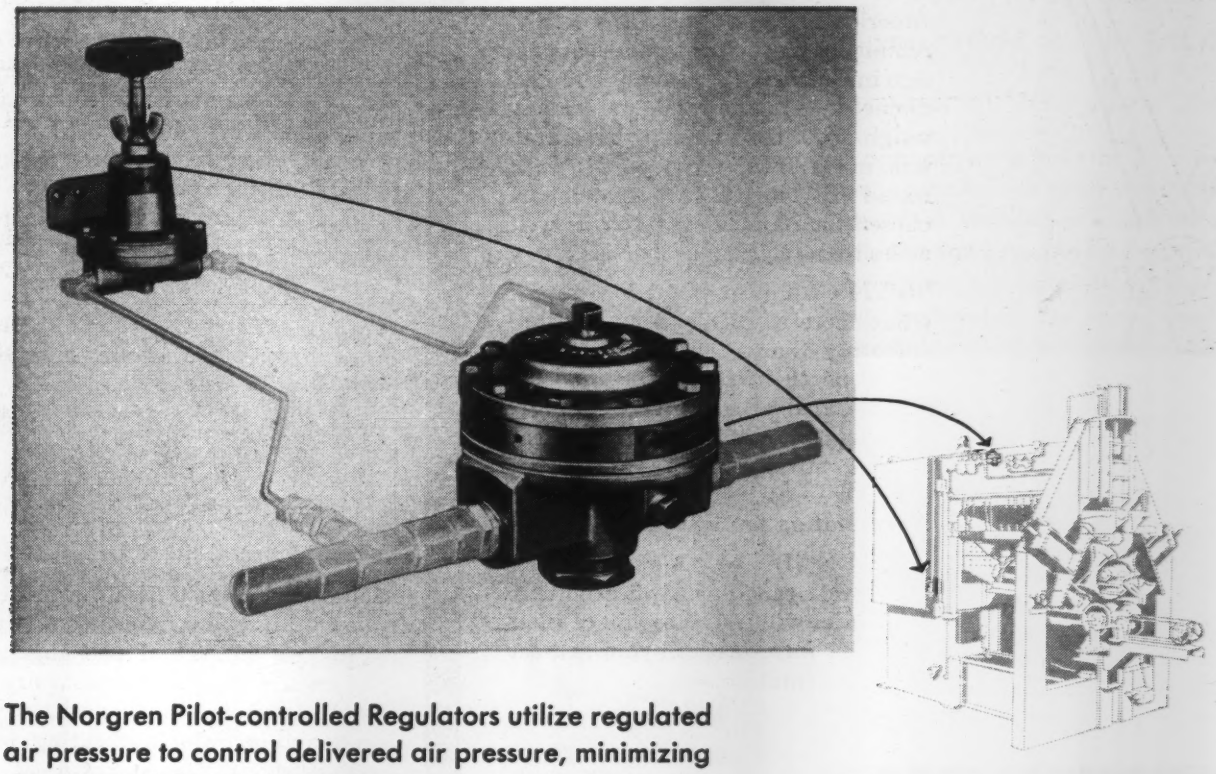
Class 8505 type C magnetic relay is designed for use with single-phase capacitor-start motors requiring a voltage-sensitive relay to disconnect start winding or reduce capacitance when motor approaches full speed. Unit is assembled on a molded phenolic base and is 2 11/16-in. high, 1 15/16-in. wide and 2⅓-in. deep. Clapper-type magnet has permanent air gap, knife-edge bearing, ground sealing surfaces and heavy shading coil. Double-break silver-to-silver contacts handle up to 50 amp on 115-v motors and 35 amp on 230-v motors. Magnet coils are available



Norgren PILOT-CONTROLLED REGULATORS

give

- extreme precision in air control
- flexibility and convenience with remote control



The Norgren Pilot-controlled Regulators utilize regulated air pressure to control delivered air pressure, minimizing the effect of fluctuating line pressure as a factor in delivering uniform working air pressures. No heavy adjusting springs . . . adjustment is easy and precise.

Remote control unit provides maxium flexibility and efficiency in machine design and plant layout . . . Pressure regulator can be placed where it is most effective, and pilot control regulator installed at most convenient location.

Available in ½", ¾", 1" sizes in both remote control and integral types for 2 psi to 120 psi delivery pressure.

PIONEER AND LEADER IN OIL-FOG LUBRICATION FOR 26 YEARS

- Valves
- Filters
- Regulators
- Lubricators
- Hose Assemblies

WRITE NOW FOR NEW CATALOG No. 600

C. A. Norgren CO.
3442 So. Elati, Englewood, Colo.

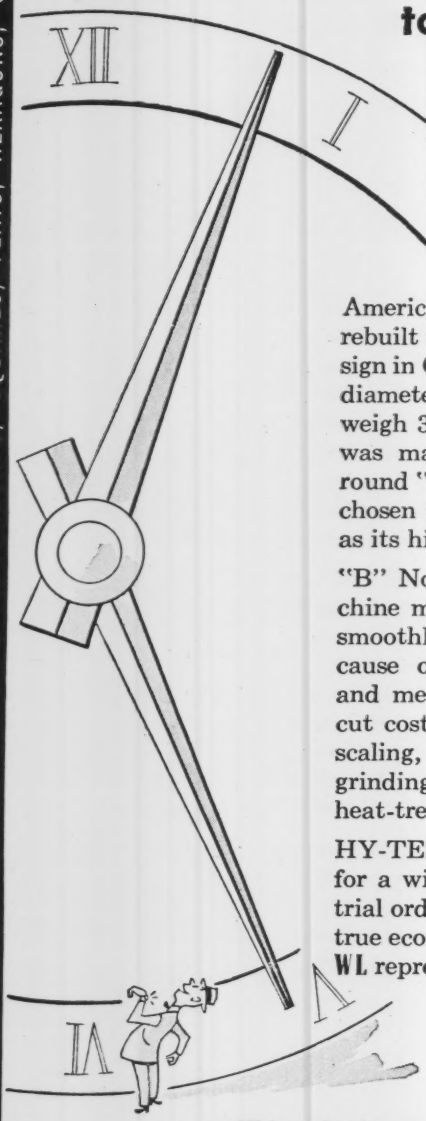
OVER ONE HUNDRED YEARS OF CONTINUOUS SERVICE. ROUNDS, SQUARES, FLATS, HEXAGONS, OCTAGONS

it's the right time

to Investigate the Qualities of

HY-TEN

ALLOY STEEL



America's largest clock was recently rebuilt for a spectacular illuminated sign in Chicago. It measures 50 ft. in diameter — hands and movement weigh 3000 lbs. The new driveshaft was made from 6 ft. of 3½-inch round "B" No. 3X heat-treated bar, chosen for its machinability as well as its high physical properties.

"B" No. 3X heat-treated bars machine more readily and finish more smoothly than standard alloys because of their particular analysis and method of manufacture. They cut costs by eliminating distortion, scaling, straightening — and often grinding — as well as the cost of heat-treating finished parts.

HY-TEN "B" No. 3X bars are used for a wide range of applications. A trial order will convince you of their true economy. Just call your nearest WL representative.

Write today for your FREE COPIES of Wheelock, Lovejoy Data Sheets, indicating your title and company identification. It contains complete technical information on grades, applications, physical properties, tests, heat treating, etc.

BILLETS AND FORGINGS FOR PRODUCTION, TOOL ROOM AND MAINTENANCE REQUIREMENTS

WHEELOCK, LOVEJOY & COMPANY, INC.

Warehouse Service

CAMBRIDGE • CLEVELAND
CHICAGO • HILLSIDE, N. J.
DETROIT • BUFFALO
CINCINNATI

In Canada
SANDERSON-NEWBOULD, LTD., MONTREAL

HY-TEN and AISI

133 Sidney St., Cambridge 39, Mass. and Cleveland • Chicago • Detroit Hillside, N. J. • Buffalo • Cincinnati

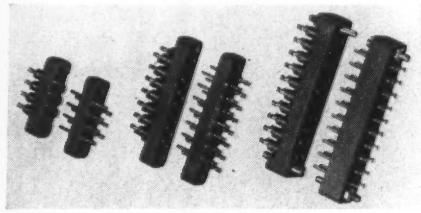
New Parts

for continuous duty ratings up to 480 v, 60 cycles or 300 v, 25 cycles. Made by **Square D Co.**, 4041 N. Richards St., Milwaukee 12, Wis.

For more data circle MD-112, Page 223

Turret Terminal Connectors

Series 16T precision power connectors, for heavy-duty service in applications requiring current capacities of No. 16 AWG wire, disengage at forces of 3 oz minimum and 8 oz maximum, without sacrificing millivolt drop. Turret type socket and pin contacts, made of spring-temper phosphor bronze and brass, respectively, are available in 7, 10, 15, 18 and 20 contact models



and are assembled in a floating, nonrotating arrangement which provides individual self-alignment of each contact. Contacts are silver plated and have positive wiping action. Contact rating is 10 amp; voltage breakdown at sea level is 4700 v rms. Insulating materials available are mineral-filled Melamine, Plaskon reinforced alkyd type 440A and diallyl phthalate. Anodized aluminum hoods with side or top openings are available. Supplied by **DeJur Amsco Corp.**, 45-01 Northern Blvd., Long Island City 1, N. Y.

For more data circle MD-113, Page 223

Retaining Rings

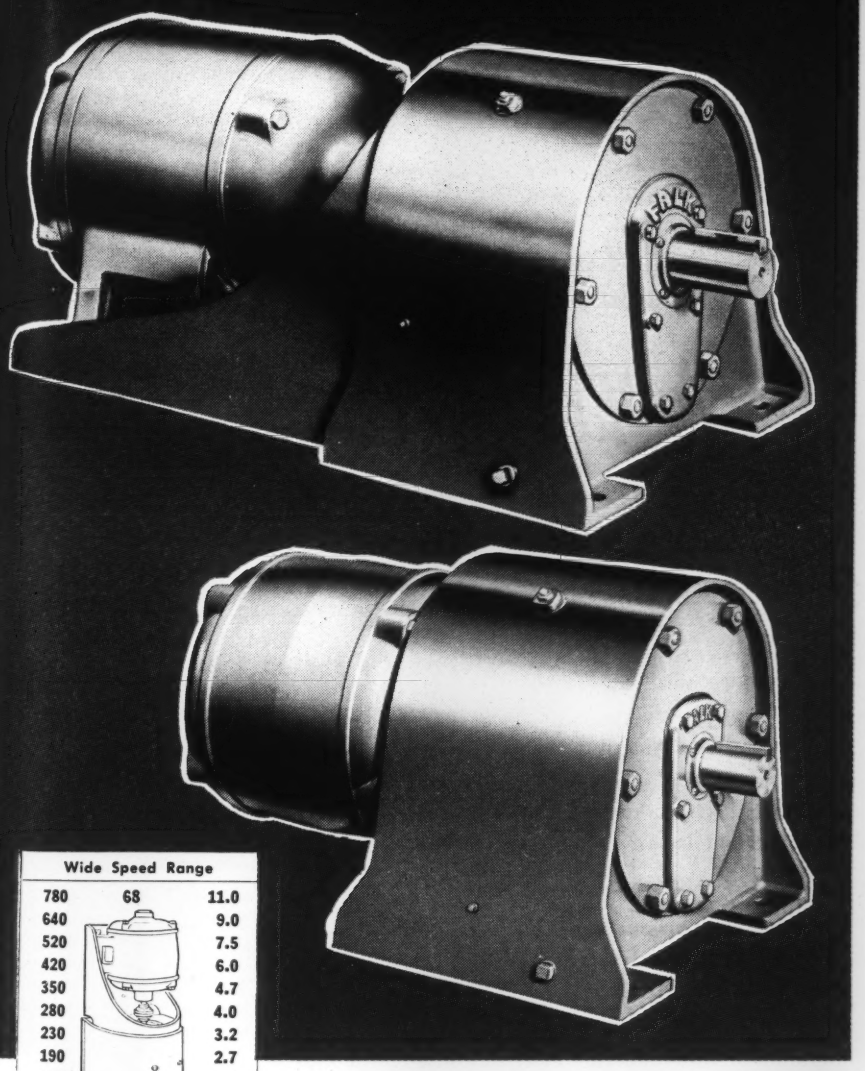
Available in carbon spring steel, beryllium copper and phosphor bronze, 0.062-in. diameter retaining rings are stacked on meal rods for fast assembly. Rings support heavy thrust loads and vibration without displacement and can be re-used without loss of resiliency. Cast iron base and applicator tool

Both... All-Motor and Integral

ALL-STEEL FALK Motoreducers

use *complete* motors with *no* modifications

...another important reason why you should consult FALK!

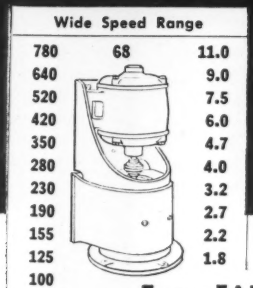


Your customers never have the annoying problem of motor modification when you standardize on *all-steel* FALK Motoreducers. Both the universally popular All-Motor type and the newly redesigned Integral type use *completely standard motors without modification.* The motor can be quickly and easily replaced by another standard motor of any make, type or speed within the unit's AGMA rating when necessary without disturbing the reducing unit.

Many choose the All-Motor type because it permits easy interchange of motors, *or even parts,* on the job, *in minutes*—with a minimum of down time. Others like the new Integral type with standard D-flange NEMA motor because it is a highly compact, streamlined unit providing the utmost in space economy.

In every FALK Motoreducer—All-Motor or Integral—the output speed (ratio) can be changed within the unit's torque capacity without modifying the motor.

Both types contribute to your industrial equipment all the quality, adaptability, dependability and long-range economy for which FALK has been celebrated for more than sixty years. FALK Motoreducers are available in standard ratio for stock shipment. Write to Dept. 247.



Every FALK Motoreducer has these "In-built" Factors—

Wide Speed Range. Selective ratio combinations provide output speeds from 1.5 rpm to 1430 rpm with stock gears.

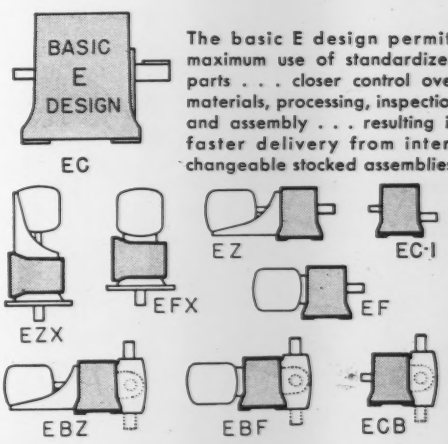
Sealed Housings. Dual closures and one-way vents keep oil *in,* dust and moisture *out.* Units are splash-proof, leakproof, dustproof.

Precision Gearing. Heat treated alloy steel, precision cut and shaved helical gearing throughout . . . quiet-operating crown shaved pinions . . . taper bored gears for easy ratio changes.

All-steel Housings. Unbreakable, strong, rigid. Generous overhung load capacities provided by wide bearing spans, large shafts and bearings.

Streamlined inside and outside. Smooth, clean surfaces; machine welded construction conforms to NEMA motor frames.

Positive Lubrication. Large sump capacity . . . oil-tight construction assures clean lubricant . . . direct dip of revolving elements provides positive lubrication at all speeds.

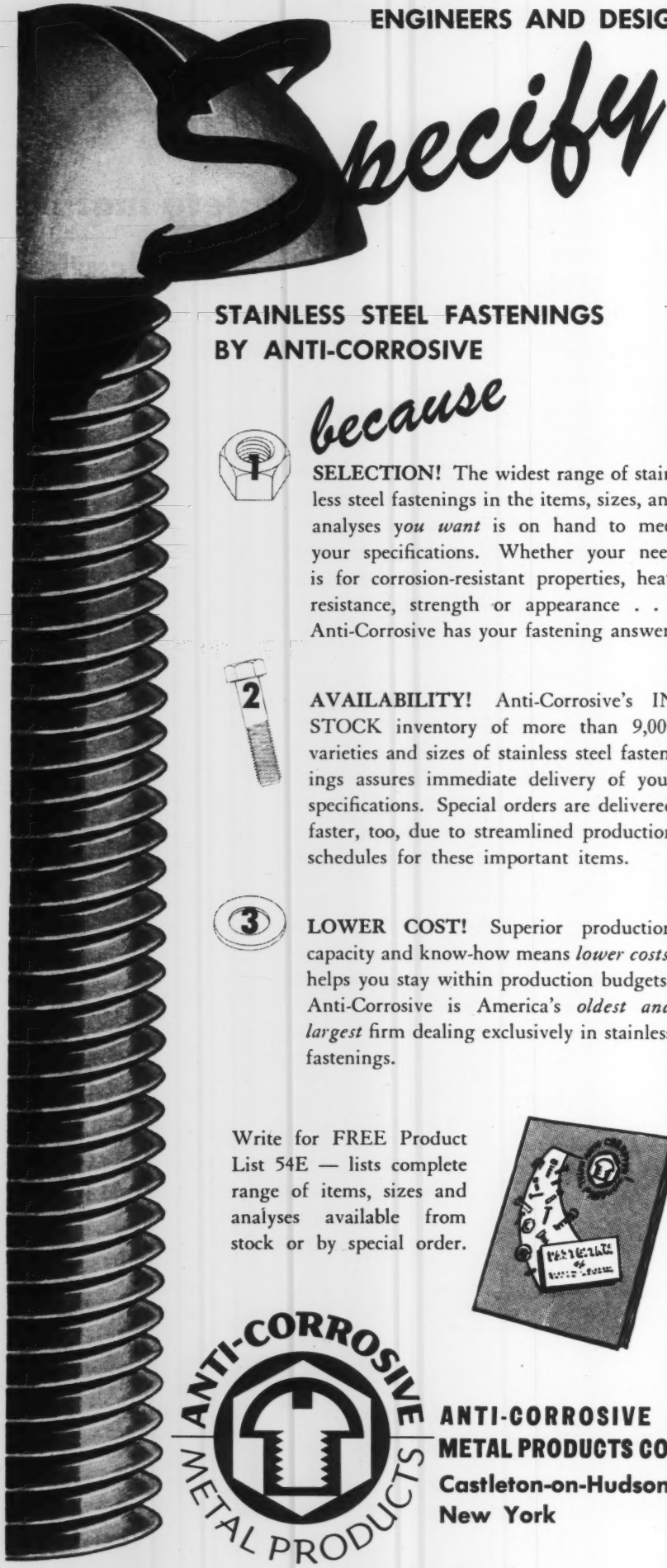


The basic E design permits maximum use of standardized parts . . . closer control over materials, processing, inspection and assembly . . . resulting in faster delivery from interchangeable stocked assemblies.

FALK ...a good name in industry

THE FALK CORPORATION 3001 W. Canal St. Milwaukee 8, Wis.

WRITE TO DEPARTMENT 247



ENGINEERS AND DESIGNERS

Specify

STAINLESS STEEL FASTENINGS
BY ANTI-CORROSIVE

because

1

SELECTION! The widest range of stainless steel fastenings in the items, sizes, and analyses *you want* is on hand to meet your specifications. Whether your need is for corrosion-resistant properties, heat-resistance, strength or appearance . . . Anti-Corrosive has your fastening answer!

2

AVAILABILITY! Anti-Corrosive's IN STOCK inventory of more than 9,000 varieties and sizes of stainless steel fastenings assures immediate delivery of your specifications. Special orders are delivered faster, too, due to streamlined production schedules for these important items.

3

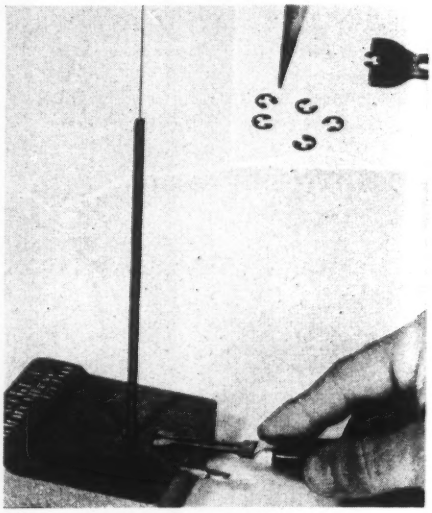
LOWER COST! Superior production capacity and know-how means *lower costs,* helps you stay within production budgets! Anti-Corrosive is America's *oldest and largest* firm dealing exclusively in stainless fastenings.

Write for FREE Product List 54E — lists complete range of items, sizes and analyses available from stock or by special order.

ANTI-CORROSIVE METAL PRODUCTS

ANTI-CORROSIVE METAL PRODUCTS CO., INC.
Castleton-on-Hudson, New York

New Parts

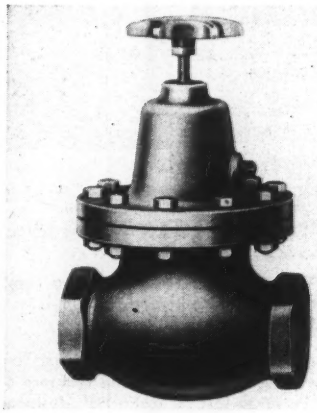


are supplied free with initial order. Made by **Industrial Retaining Ring Co.,** 8 W. Sidney Ave., Mt. Vernon, N. Y.

For more data circle MD-114, Page 223

Control Valves

Type KD back pressure valves automatically maintain a constant back pressure on the inlet side, regardless of suction pressures at the valve outlet and load and demand



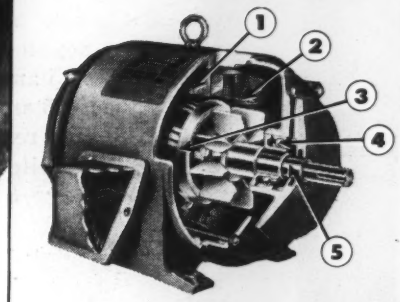
changes. Because of multiple ported internal unit, valve has large capacity on low pressure differences. They are available in pipe sizes ranging from ½ to 2 in., with screwed ends and with or without a handwheel for manual pressure setting. Remotely controlled pressure setting arrangement is also available. Units are suitable for any back pressure from 0 to 75 psi,

It stood up to weather's worst

DOWN UNDER

...BROOK MOTORS *can meet your temperature conditions, too!*

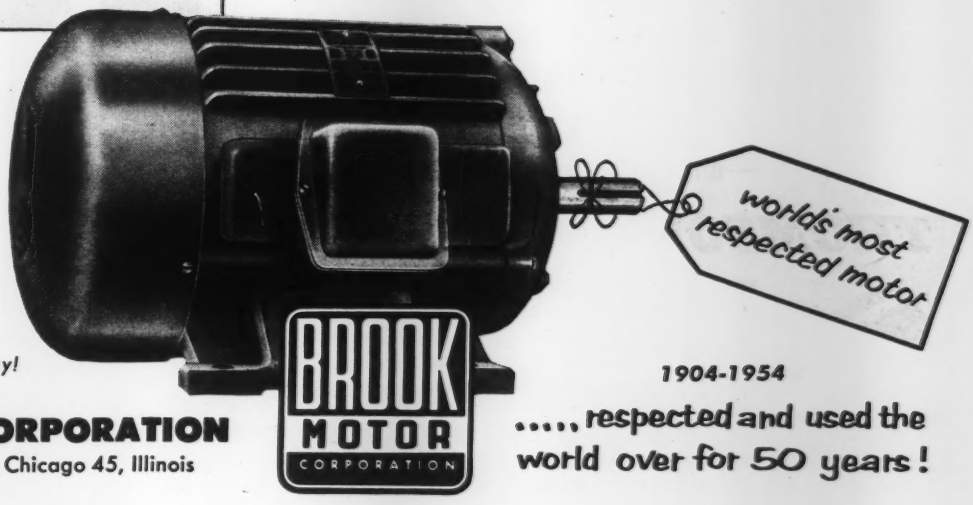
Dry swirling dust or penetrating moisture . . . broiling desert heat or below-freezing cold . . . it takes a tough motor to stand up to variable climatic extremes. Famous Brook AC electric motors are *especially built* to the operating conditions found anywhere in the U. S. and in any foreign country. Mica-insulated stator slots and windings are impregnated and baked to resist heat, cold, dust and moisture. Every Brook motor is designed and precision built to meet or surpass NEMA standards. Easily serviced in any shop, parts and motors quickly obtainable everywhere. Ideally suited for original equipment manufacturers, for users of equipment requiring replacement motors, and for products destined for export. Whatever *your* needs, insist on Brook . . . the world's *most respected* motor—built by the world's *most experienced* manufacturer.



1. **Ceramic-coated stator laminations** provide excellent dielectric qualities and maximum resistance to heat.
2. **Stator slots insulated with mica-coated fabric**—highly resistant to water, oil, heat and electrical strain.
3. **Dynamically-balanced rotors** to eliminate vibration . . . a practically indestructible unit of pure copper or aluminum passing through rotor laminations.
4. **U. S. standard interchangeable ball bearings** in metric sizes. Mountings protected against dirt and moisture.
5. **Precision-ground shaft**—painstakingly ground to the highest, most exacting standards. Made of the finest, high tensile steel.
6. **All major types**—available from stock . . . open drip-proof, splash-proof, totally enclosed non-ventilated, totally enclosed externally fan-cooled . . . in a wide range of horsepower sizes.

Write for FREE catalog!

Get all the details about the complete Brook line . . . write today!



world's most respected motor

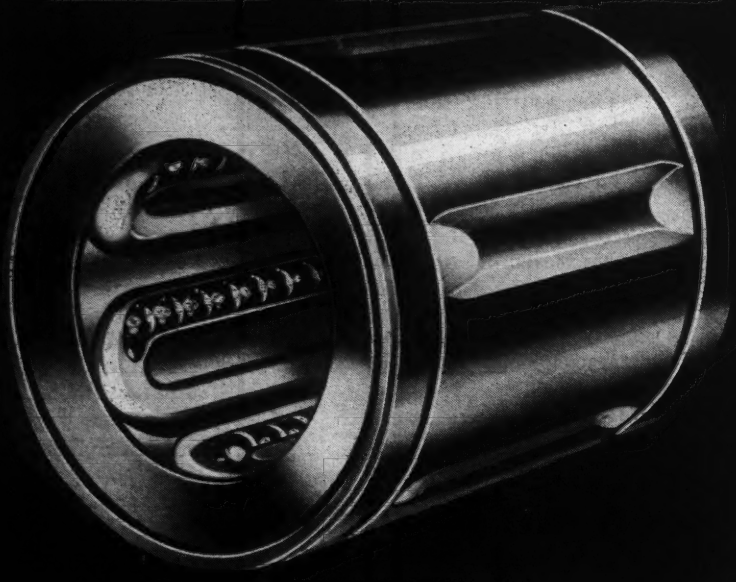
BROOK MOTOR CORPORATION

3555-57 W. Peterson Avenue, Chicago 45, Illinois

1904-1954

. . . . . respected and used the world over for 50 years!

BALL BUSHING



The BALL BEARING for your

LINEAR MOTIONS

Sliding linear motions are nearly always troublesome. Thousands of progressive engineers have solved this problem by application of the Precision Series A or Low-Cost Series B BALL BUSHINGS.

Alert designers can now make tremendous improvements in their products by using BALL BUSHINGS on guide rods, reciprocating shafts, push-pull actions, or for support of any mechanism that is moved or shifted in a straight line.

Improve your product. Up-date your design and performance with BALL BUSHINGS!

Now manufactured for ¼", ½", ¾", 1", 1½", 2" and 2½" shaft diameters.

LOW FRICTION • LOW MAINTENANCE
ELIMINATES BINDING AND CHATTER
SOLVES SLIDING LUBRICATION PROBLEMS
LONG LIFE • LASTING ALIGNMENT

Progressive Manufacturers Use Ball Bushings —A Major Improvement at a Minor Cost

THOMSON INDUSTRIES, Inc.

Dept. E, MANHASSET, NEW YORK

Write for descriptive literature and the name of our representative in your city.

Also manufacturers of NYLINED Bearings — DuPont NYLON within a metal sleeve—for rotation and reciprocation.

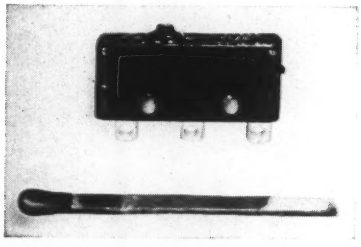
New Parts

or pressures below atmosphere. Made by **A. W. Cash Valve Mfg. Corp.**, 666 E. Wabash Ave., Decatur 60, Ill.

For more data circle MD-115, Page 223

Subminiature Switch

Measuring 27/32 x 23/64 x 0.260-in., basic switch resists shock and vibration. Action of contacts is independent of speed of actuation. Snap-action spring compression member equalizes stress on switch springs. Switch has solder type terminals and is mounted by



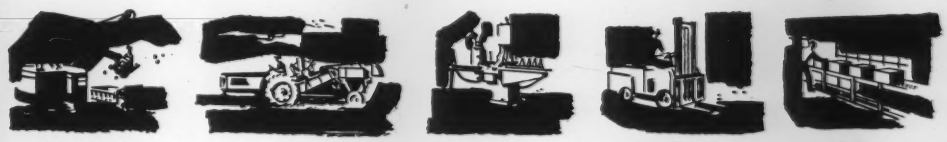
two No. 2 screws through the plastic case. Toggle, pushbutton and leaf spring actuators are available. Switch is available normally closed single-pole single-throw, normally open single-pole single-throw or single-pole double-throw. It is rated at 2.5 or 5 amp at 125 or 250 v ac; 30 v dc, 2.5 amp inductive; or 30 v dc, 4.0 amp resistive. Made by **Electro-Snap Switch & Mfg. Co.**, 4218-30 W. Lake St., Chicago 24, Ill.

For more data circle MD-116, Page 223

Speed Control

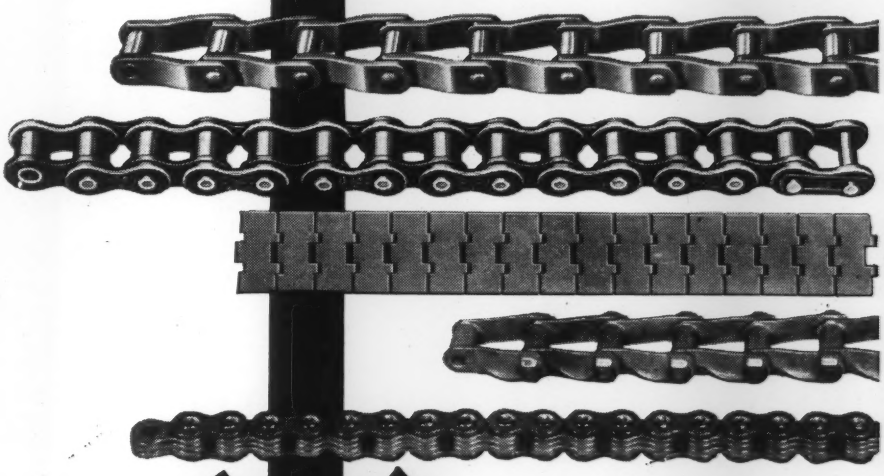
Air gap design of this speed control for fractional horsepower shaded-pole motors assures starting at low voltages and eliminates core saturation, the cause of heating, current distortion and reduced motor torque. Control can be made for three-speed operation. Three models are available: cased control, for remote control operations, with control reactor and switch mounted in an outlet box for permanent installation; panel mounted, to permit single hole mounting on panels; and

des n your machines



with these dvantages

t only CHAINS give you!



Chabelco® Chains

Roller Chains

TableTop® Chains

Cast Chains

Leaf Chains

Your Chain Belt Field Sales Engineer will be happy to help you select the size and type of chain and sprocket that will best suit your needs . . . provide the most efficient drive or conveyor at the lowest cost. Call him or mail the coupon today.

Always the one best chain for each service

CHAIN BELT COMPANY

CHAIN BELT COMPANY 54-501
4643 W. Greenfield Ave.,
Milwaukee, Wisconsin

I want information on chains for.....
Send literature on: ☐ Chabelco Chains; ☐ Roller Chains; ☐ TableTop; ☐ Leaf Chains; ☐ Cast Chains; ☐ Sprockets. ☐ Have a Chain Belt Man call.

Name.....

Company.....

Address.....

City.....*Zone*.....*State*.....

1

Self-oiling composition bushing feeds oil to shaft by capillary action.

2

Bushing has shoulder which provides self-lubricating bearing surface for collar.

3

Slotted Bolt Holes. Rubber grommets can be used for sound isolation.

4

Absorbent filler holds oil in reservoir and prevents over-lubrication.

5

Split Pressed Steel Housing is light and strong.

6

Spherical surfaces provide full self-alignment.

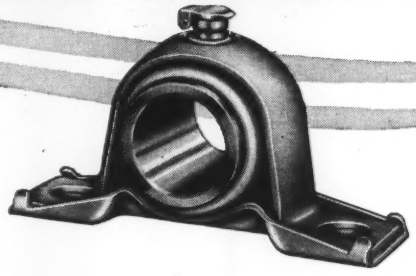
DODGE

Bronzoil

FAN AND BLOWER BEARINGS

Proved

in Millions of installations!



Engineered to meet the specialized requirements of fan and blower service, Dodge Bronzoil bearings are widely and successfully used on small shafts for general service, within the limits of their capacity. Capillary bronze bushing has a capacity of one-third its volume in oil. The liberal oil reservoir, with close fitting wick, surrounding the bushing provides ample lubrication. Millions of Bronzoil bearings have proved their dependability through years of service. Available in shaft sizes from 3/4" to 1 1/4". Write now for literature and detailed information.

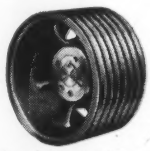
DODGE MANUFACTURING CORPORATION, 3300 Union St., Mishawaka, Ind.

DODGE

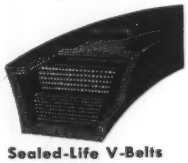
of Mishawaka, Ind.

CALL THE TRANSMISSIONEER, your local Dodge Distributor. Factory-trained by Dodge, he can give you valuable assistance on new, cost-saving methods. Look for his name under "Power Transmission Machinery" in your classified telephone book.

Dodge-Timken Bearings



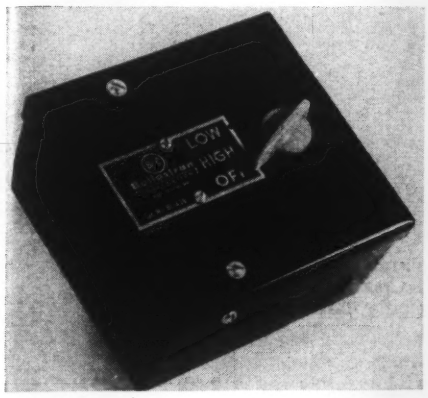
Taper-Lock Sheaves



Sealed-Life V-Belts

NAME PLATES

FOR YOUR NAME PLATE REQUIREMENTS, WRITE OUR SUBSIDIARY, CHICAGO THRIFT-ETCHING CORPORATION, 1555 N. SHEFFIELD AVENUE, CHICAGO 22, ILLINOIS



chassis mounted, for mounting control reactor within an enclosure. Controls are designed for each specific application. Made by **Ballastran Corp.**, 1701 N. Calhoun St., Ft. Wayne 7, Ind.

For more data circle MD-117, Page 223

Aluminum Alloy

Type 66S aluminum alloy has characteristics which place it between the previously available low strength type 61S and the hard 24S and 14S alloys. More easily welded than the hard alloys, it retains yield strength of 45,000 psi and has good corrosion resistance. Tensile and yield strengths are 31 per cent better than those of 61S. Applications include truck, trailer and aircraft fabrication and heavy construction. Made by **Harvey Aluminum**, 19200 S. Western Ave., Torrance, Calif.

For more data circle MD-118, Page 223

Geared Motor

Compact speed reducer is combined with shaded-pole motor in model 300 geared motor. Basic motor is two-pole induction type, available with 1/500 to 1/75-hp depending on coil and stack size. Output speeds beginning at 1 rpm are available to specification. Typical unit with output of 9 rpm at 16-w input delivers full load torque of 150 oz-in. Power required is 115 v, 50 or 60 cycles, and shaft rotation can be clockwise or counterclockwise. Unit has porous

(*Continued on Page* 276)

HOW TO SOLVE HOT SPOTS

(UP TO 2200° F)

in products and processes

If improvement of your product or process depends upon use of extremely high temperature, while minimizing its destructive effects, use Kentanium at the critical points.

WHAT is Kentanium?

Chiefly titanium carbide (and small percentages of other refractory metal carbides), with nickel "binder". Uses neither tungsten nor cobalt. Hardness: Up to 93 RA. Weight: ⅔ that of steel.

WHAT can it do?

Resist thermal shock, withstand oxidation and abrasion, retain great strength at high temperatures (1800°F and above).

WHERE is it in use?

Successful applications include: Valves, valve seats, reduction crucibles, anvils for spot welding, hot extrusion die inserts, bushings, thermocouple protection tubes, flame tubes, furnace tong tips, balls for hot hardness testing, nozzle vanes and blades for jet engines, and many others.

WHAT forms are made?

Tubes, rods, bars, flats by extrusion process. More complex parts by machining from pressed slugs before sintering; extremely accurate parts by grinding to required tolerance after furnace sintering.

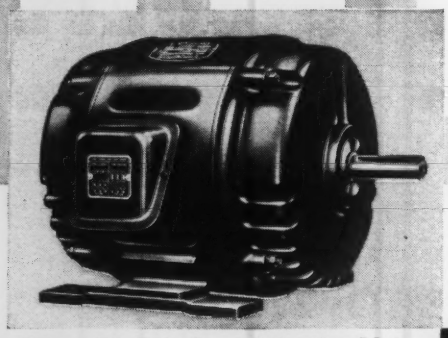
HOW can you use it?

This remarkable new metal, available in many "grades" to meet specific combinations of imposed conditions, can best be adapted to your high temperature problem by cooperative effort. Our engineers will be glad to discuss how you can get best results from Kentanium.

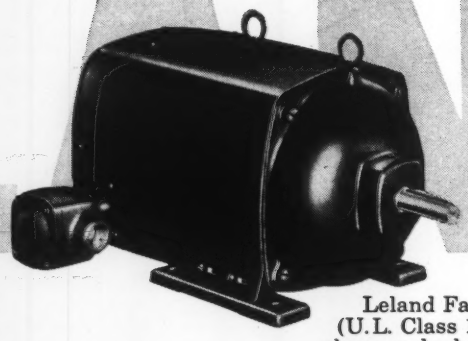
An Exclusive Development of KENNAMETAL® Inc., Latrobe, Pa.

KENTANIUM

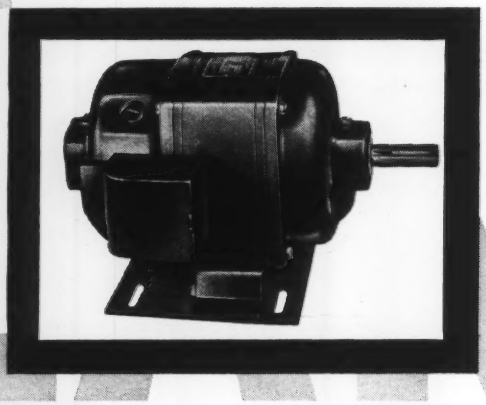
HEAT-RESISTANT, HIGH-STRENGTH, LIGHTWEIGHT CEMENTED TITANIUM CARBIDE



Leland Type PA Polyphase Induction Motor in drip-proof frame; 1/6 to 5 HP.

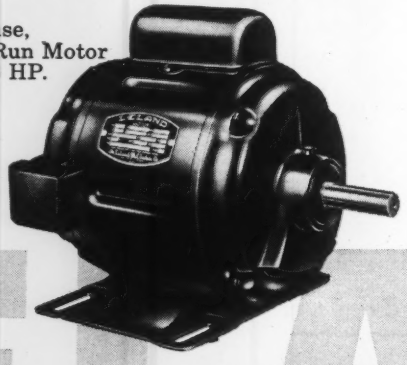


Leland Fan-cooled, Explosion-Proof (U.L. Class 1, Group D) Motor; single phase, polyphase or DC; 1/6 to 5 HP.

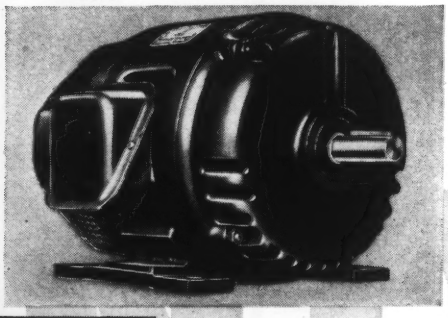


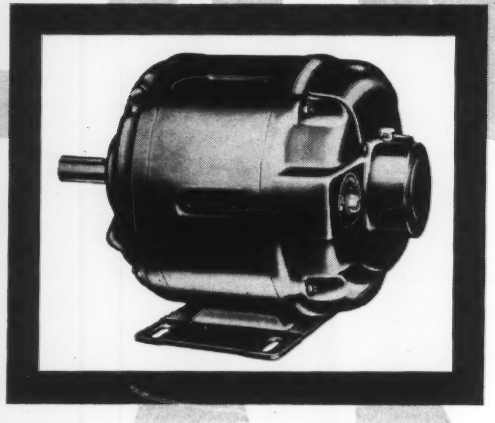
Leland Type DM Direct Current, General Purpose Motor in drip-proof frame; 1/6 to 5 HP.

Leland Type KL Single Phase, Capacitor Start, Induction Run Motor in drip-proof frame; 1/6 to 3 HP.



Leland Type RA Single Phase, Repulsion Start, Induction Run Motor in drip-proof frame; 1/3 to 5 HP.





Leland Type KS Split Phase, Induction Motor in drip-proof frame with thermal protection; 1/6 to 1/3 HP.

Though your only special need is Higher Quality...Look to Leland!

LELAND caters particularly to manufacturers who wisely demand *special quality* in *standard types* of motors, as well as those whose products require motors with special features or modifications.

We at Leland have always been keenly conscious of the unique part a good motor plays in product performance and user satisfaction. That's why we have—for more than 30 years—built Leland motors to highest standards of quality...never down to a price!

Under this policy, our engineers work closely and effectively with our customers to provide Leland motors—either standard or special—which meet exactly the application's particular requirements. As a result, Leland motors have established enviable records for trouble-free service in many fields.

Even though your only *special* motor need may be for higher quality, look to Leland to provide it. In the range between 1/6 and 5 HP, the selection of types and sizes is exceptionally broad. Write or wire for location of our local representative.

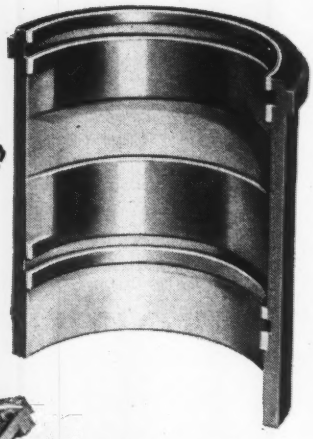
The LELAND ELECTRIC Co.

DAYTON 1, OHIO

Division of AMERICAN MACHINE & FOUNDRY COMPANY, New York
In CANADA, Leland Electric Canada, Ltd., Guelph, Ontario

amf products are better...*by design*

Babbitt and Backing are ONE



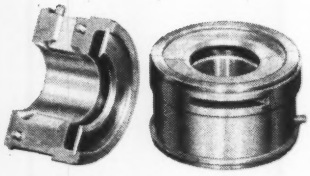
Here's Proof

Perfect bond between babbitt and backing remains unbroken in this babbitt-lined, steel-backed bearing flattened under terrific pressure.

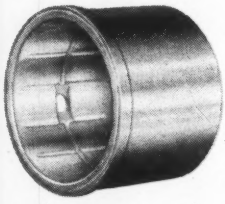
in WAUKESHA "Centri-Fuse" BEARINGS

Special preparation of the backing, by the Kolene process . . . plus the most advanced practices in centrifugal casting, under precision control . . . results in an actual chemical bond (metal-to-metal fusion) between babbitt and backing which eliminates the need for anchor slots. Uniform crystalline structure of the babbitt, resulting from this method of centrifugal casting, assures maximum fatigue resistance and long life for Waukesha Bearings of any design, under heavy pressure or shock loads.

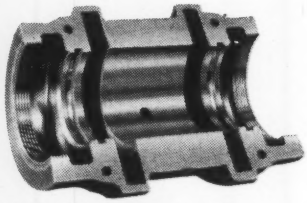
Specialized facilities for long or short production runs, rigid inspection procedures, and the counsel of an engineering staff . . . devoted exclusively to the design and fabrication of babbitt-lined bearings and oil seals . . . are yours to command at WAUKESHA.



A Waukesha Split Bearing for use in high speed turbines.



Waukesha Sleeve Bearing for heavy duty compressors in almost constant use.



A Waukesha bearing of complex design for a widely known manufacturer of generators.

"Just ONE Bearing or a LONG Production run!"

WAUKESHA Bearings

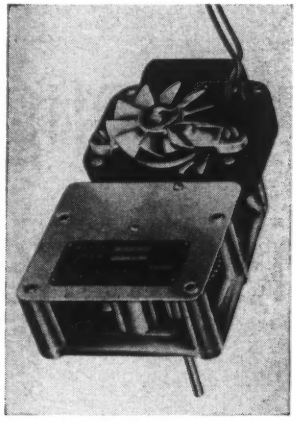
Division of WAUKESHA TOOL CO., Waukesha, Wisconsin

A 7743-2/3

New Parts

(*Continued from Page* 273)

bronze bearings and large oil reservoir, cooling fan, nylon high speed gears, and vacuum impregnated

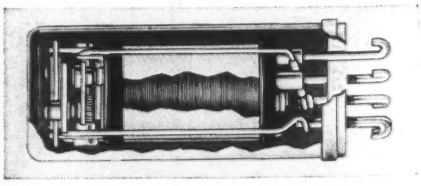


paper layer coils. Made by **Loral Electronics Corp.**, 794 E. 140th St., New York 54, N. Y.

For more data circle MD-119, Page 223

Miniature Relay

Hermetically sealed type PW miniature relay is direct current actuated and has balanced armature construction that withstands 10*g* vibration at up to 500 cycles per second during operation. Needle point pivot bearings afford friction-free movement. Dimensions are 0.756 x 1.656 in. above chassis and weight is 1 1/16-oz.

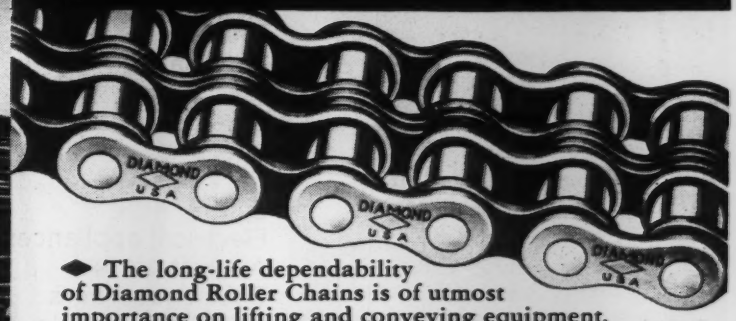


Contact arrangement is single-pole, double-throw, and contacts are 3/32-in. diameter pure silver, rated at 2 amp at 28 v dc or 115 v, 60 cycles ac noninductive load. Coil ranges are from 100 to 16,000 ohms; actuation may be by current or voltage; operating power is 25 milliwatts to 1.5 w. Made by **Potter & Brumfield,** 1200 E. Broadway, Princeton, Ind.

For more data circle MD-120, Page 223

DIAMOND ROLLER CHAIN DRIVES

For Hydraulic Transverse Cylinders on Baker-Lull Traveloaders



SHOT-PEENING SINCE 1944

Diamond Chain has long recognized that certain types of internal stressing of chain parts would increase fatigue resistance. To this end, link plates have been specially processed and chain rollers and other parts have been shot-peened since 1944.

PITCH HOLE PREPARATION

Maximum rigidity of links insured by special pitch hole preparation for 100% effective bearing area of pin and bushing. Longer life, smoother operation.

◆ The long-life dependability of Diamond Roller Chains is of utmost importance on lifting and conveying equipment.

On Baker-Lull Traveloaders the hydraulic transverse cylinders are driven by two-strand Diamond Roller Chains. The chain drive serves two purposes—one to propel the lifting tower in and out, and the other to equalize the pressure in the two transverse cylinders.

Speed ratios are definitely maintained, there is no slippage and shafts can be close together or far apart to meet design requirements.

For over 63 years Diamond Roller Chains have proven their reliability on equipment and machinery built by America's leading manufacturers . . . Practical recommendations by our experienced engineering staff can help save your time in arriving at correct applications. Your inquiry is awaited.

DIAMOND CHAIN COMPANY, Inc.

Where High Quality is Traditional

Dept. 435, 402 Kentucky Avenue, Indianapolis 7, Indiana

Offices and Distributors in All Principal Cities

DIAMOND **ROLLER CHAINS**

YOU NAME IT-

FELT

by FELTERS

will do it...

Filters
Auto parts
Washers
Noise dampeners
Wicks
Packings
Liners
Electrical appliances
Aircraft parts
Shock absorbers
Vibration controls

(Your product goes here)

Resiliency that permits constant spring-back to original shape . . . and good absorptive characteristics . . . are just two of the many properties you can get in Felt made by Felters.

If you have a problem that could be solved by a soft, porous material, or by a hard, dense material — your answer could well be a Felt made by Felters.

The "Felters Design Book" describes several usual and unusual uses for Felt. Drop us a line and we will send you a copy.

HEARD ABOUT **UNISORB®** *— THE MODERN MACHINERY MOUNTING?*

The **FELTERS** Company
218 South Street, Boston 11, Mass.

ENGINEERING DEPARTMENT

EQUIPMENT

DC Power Supply

Line of direct current power supplies includes a cabinet-mounted type with output voltage range up to 300 v and a series of subchassis mounting type packages with dc voltages ranging from 150 to 500 v. Ripple on all units is

below 0.01-v, peak to peak, at full load. Regulation ranges from 0.5 to 1 per cent from no-load to full load with ±10 per cent line voltage variation. Made by **Dressen-Barnes Corp.**, 250 N. Vinedo Ave., Pasadena 8, Calif.

For more data circle MD-121, Page 223

Aluminum Modeling Compound

Formulated of virgin aluminum, resins and aliphatic solvents, Sculp-Metal can be modeled like clay by designers or modelmakers. It air hardens into a metal which is harder than lead. Spread with spatula-like tools or the fingers, the material is applied in successive layers about ⅛-in. thick. Layers fuse together into an integrated mass. Hardened metal may be carved, drilled, tapped, machined and finished to desired smoothness. When completely

for lower cost control of moderately **Corrosive** fluids

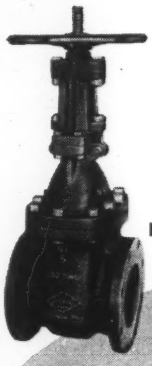


Fig. 2651-A Gate

JENKINS

NICKEL IRON

Valves with Type 316

STAINLESS STEEL

Trim

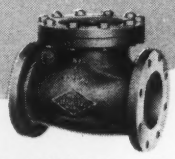
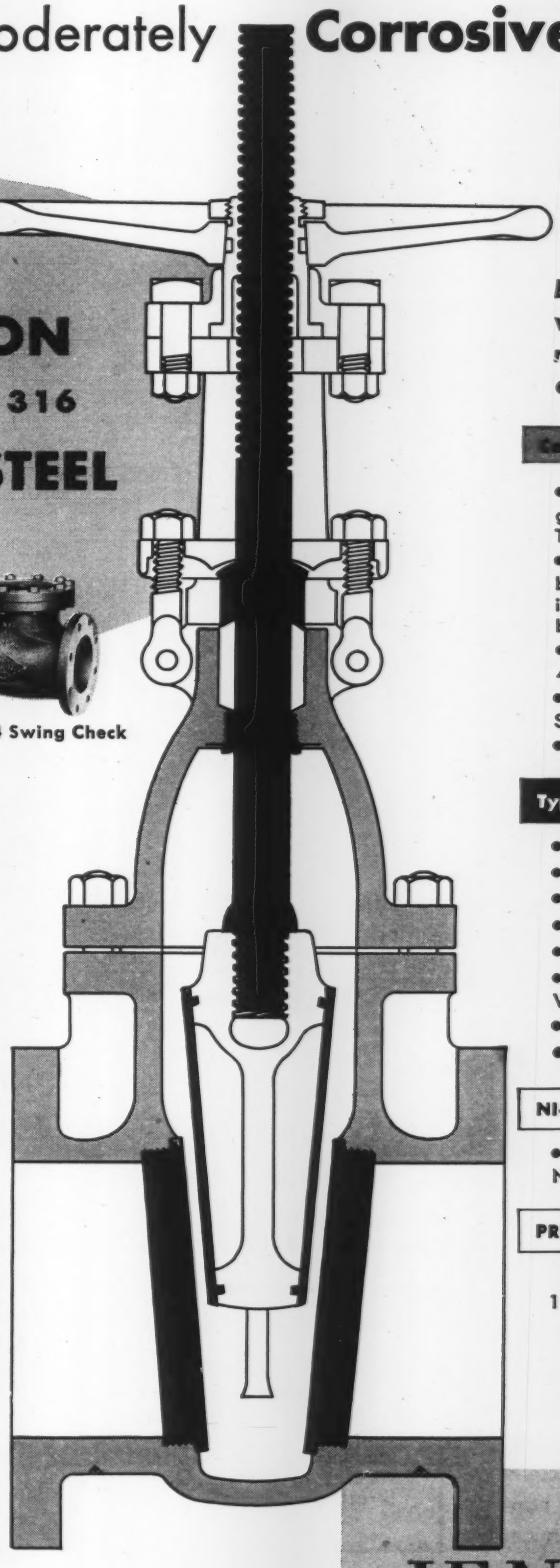


Fig. 2624 Swing Check



Every part in contact with fluid is the right metal to block corrosion and beat wear.

Cast NICKEL IRON

- **BODIES** Heavy duty, dimensioned for greater resistance to wear and abuse. Through port design in Gate Valves.
- **BONNET** Rugged construction, like body. Swing-type gland bolts. Screwed-in back-seating bushing. Deep stuffing box.
- **YOKE** Integral with bonnet in 2″ to 4″ sizes.
- **WEDGE** In 10″ to 24″ sizes, with Stainless Steel Wedge Rings.
- **COVER** In Check Valve.

Type 316 STAINLESS STEEL

- SPINDLE
- GLAND
- BONNET BUSHING
- SPINDLE RING
- WEDGE PIN
- WEDGE RINGS Rolled into Nickel Iron Wedge in 10″ to 24″ sizes.
- SEAT RINGS
- DISC and HANGER in Check Valve

NI-RESIST Type No. 2

- WEDGE of I-beam structure is solid NI-RESIST in 2″ to 8″ sizes.

PRESSURE RATINGS

2″ to 12″—200 lbs. O.W.G.
14″ to 24″—150 lbs. O.W.G.

This combination provides corrosion resistance well above the moderate need in many processing services with an investment well below that for all-stainless steel valves.

Designed primarily for the chemical process industries, they are recommended for control of mildly corrosive liquids with minimum quantities of mineral acids, such as creosote in wood treatment, and many liquids carried in petroleum processing.

A major use is in pulp and paper processing, particularly in lines serving the digester, and in the chemical recovery cycle. Service records in lines carrying the valve-punishing "black liquor" give Jenkins Nickel Iron Valves top performance rating.

Jenkins *extra value* construction throughout. Get details — compare. See why they stretch your valve investment dollar — with longer service life, lower maintenance cost.

GET COMPLETE SPECIFICATIONS from your Jenkins Valve Distributor, or write: Jenkins Bros., 100 Park Ave., New York 17. Ask for Bulletin 118.

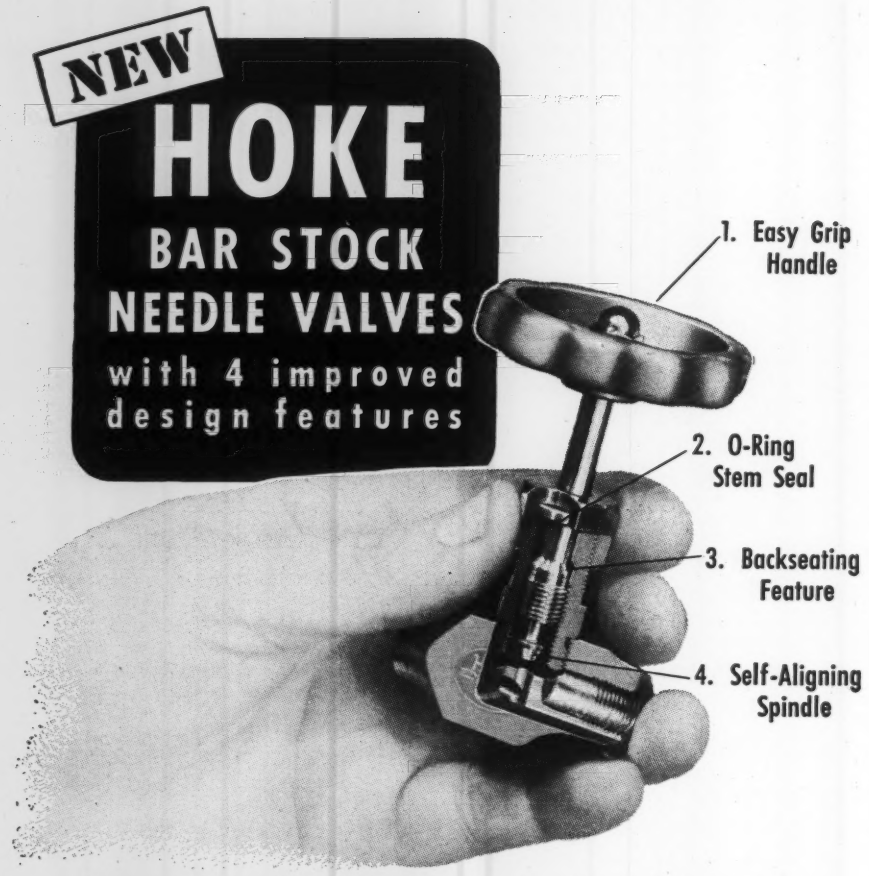
JENKINS

LOOK FOR THE DIAMOND MARK

VALVES

SINCE 1864 TRADE JENKINS MARK

Jenkins Bros



The newest and most versatile bar stock needle valve now available—that's the HOKE 270 series for instrumentation, test panel and hydraulic service. The O-ring stem seal provides maximum tightness and eliminates packing adjustments. (Conventional packing is available, however, if desired.) An important new advantage is the backseating feature that permits O-ring or packing replacement under pressure, without shutting down. A self-aligning spindle has been designed to insure tight seating with minimum wear. The easy-grip handle is of die-cast anodized aluminum, with no sharp edges. An additional feature makes possible direct instrument panel mounting. These new bar stock valves are now available in sizes from ⅛" to ½" pipe — straight and angle patterns — manufactured from brass, Type 316 or 430F stainless steel. O-ring styles can be helium leak tested for use in non-critical high vacuum service.

Write for the New Hoke Catalog

This completely illustrated 68-page catalog contains specifications on needle valves of all sizes as well as toggle valves, special purpose valves, fittings and accessories. Tell us about your problem and we will gladly send you a copy of the catalog with our specific recommendations. Address your request to 191 S. Dean Street, Englewood, N. J.

HOKE
HOKE INCORPORATED
Fluid Control Specialists
ENGLEWOOD, NEW JERSEY

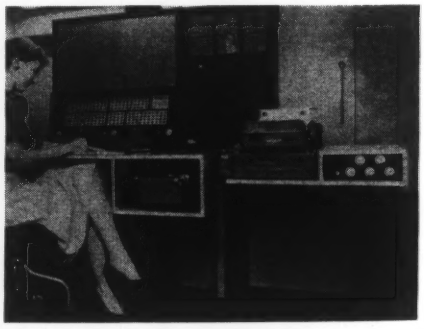
Engineering Equipment

cured, it will not shrink, crack, chip or peel. It withstands temperatures from −65 to 350 F, is weather and rustproof and resists gasoline, oils, greases, alkalies and most acids. It can be painted with lacquers, synthetic enamels and oil base paints, without the use of a primer. Thinned with a special solvent, the material itself can be sprayed or brushed over wood, plaster and other materials to form a watertight aluminum skin. Made by **Sculp-Metal Co.**, 701 Investment Bldg., Pittsburgh 22, Pa.

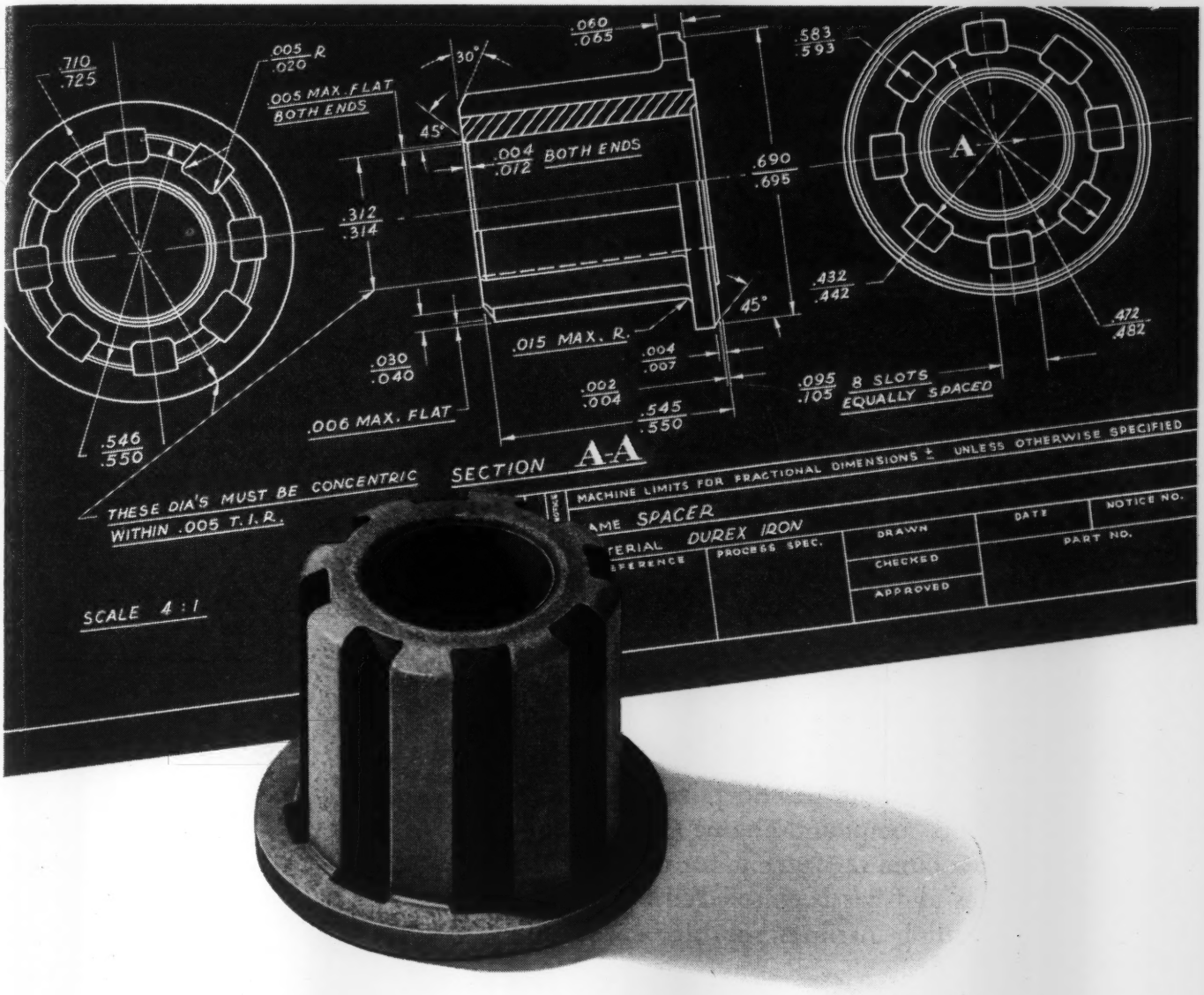
For more data circle MD-122, Page 223

Electronic Computer

Adaptable to scientific and industrial problems which can be reduced to numerical terms, model 203 digital computer employs a binary-coded decimal system in which four binary digits form each decimal digit. It solves problems



in aircraft flutter studies and boiler design. Computer combines a magnetic-drum type "memory" with a wide choice of input and output methods ranging from standard punched card techniques to special photoelectric readers. Speed of operation ranges from divisions at an average rate of 85 per second to additions at 500 per second. Maximum storage capacity of the memory section is 1,600,000 ten-digit words, a "word" being either a number to be used in computation or a command to the computer to perform a specific operation. Maintenance is facilitated by built-in test circuits and controls, standard quickly repleaceable plug-in components



TRICKY DESIGNS ARE EVERYDAY PROBLEMS FOR MORAINE'S METAL POWDER PROCESS

This part would be a *real* problem to make economically by conventional casting and machining methods. At Moraine it's made from metal powder—easily, in quantity, every day—to precision standards—with important savings in cost!

The background print shows clearly the intricacies and the close tolerances demanded by this part. Yet at Moraine it is produced *completely finished* after *one* press operation. Here's proof of what can be done through close cooperation between Moraine and customer.

The contributions of Moraine's metal powder process to industry are growing day by day. Complex designs like this are being produced by Moraine with great performance-improving, cost-cutting results for many customers.

m

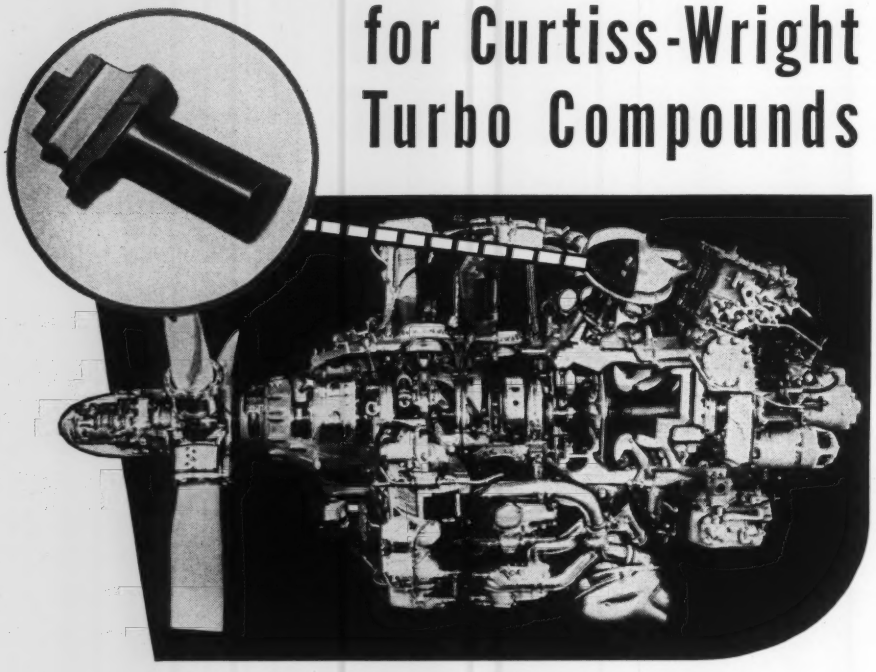
moraine products

DIVISION OF GENERAL MOTORS CORPORATION, DAYTON, OHIO

METAL POWDER PARTS

Buckets by MISCO

for Curtiss-Wright Turbo Compounds



This intricate bucket is an integral part of the power recovery units in the powerful Curtiss-Wright Turbo Compound Engine (shown above) which is now rated at 3700 h.p. for the U. S. Military Services and has been selected by 22 of the World's Leading Airlines for high-speed, long range transports.

Production of this complicated component clearly constitutes a notable MISCO achievement in practical engineering, metallurgical knowhow, and highly skilled techniques to meet the most exacting requirements.

For Castings of Greater Dependability, Better Performance and Longer Service Life, Specify

MISCO

PRODUCERS OF AIRCRAFT AND INDUSTRIAL INVESTMENT CASTINGS

Misco Precision Casting Company

DIVISION OF IOWA-MICHIGAN CORPORATION

DETROIT DIVISION
253 St. Aubin Avenue
DETROIT 7, MICHIGAN
Lorain 7-1545

WHITEHALL DIVISION
116 West Gibbs Street
WHITEHALL, MICHIGAN
Whitehall 2-1515

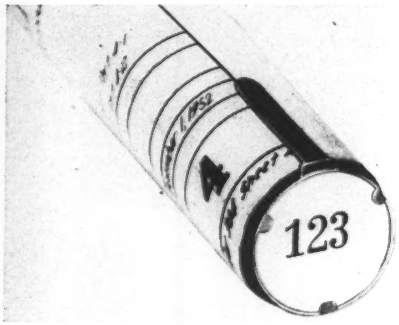
Engineering Equipment

and a maintenance panel. Unit can be operated by comparatively unskilled personnel after it is set up for individual problems. Made by **Consolidated Engineering Corp.**, 300 N. Sierra Madre Villa, Pasadena 8, Calif.

For more data circle MD-123, Page 223

Blueprint Label

Adaptable to the pigeonhole system of filing engineering drawings and blueprints, label is placed on the ends of rolled papers. The label fits into a circular metal

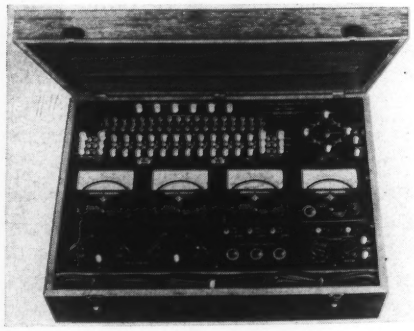


head, joined to a brass spring clip which grips the drawing. Various colors are available. Made by **Ulrich Planfiling Equipment Corp.**, 421 Murray Ave., Jamestown, N. Y.

For more data circle MD-124, Page 223

Universal Test Set

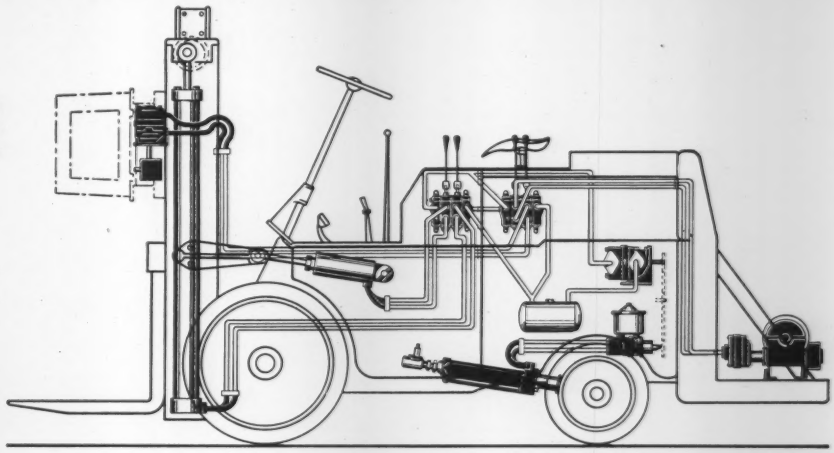
Four separate rate measuring instruments are supplied with internal resistances and shunts, as well as a basic Wheatstone Bridge circuit, a four-dial decade box, fine and coarse potentiometers,



VICKERS® HYDRAULICS

The MARK of SUPERIOR MATERIALS HANDLING EQUIPMENT

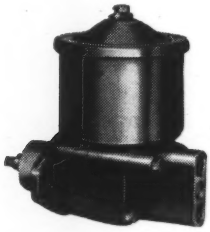
Fork lift truck uses Vickers Hydraulics in one circuit for lift, tilt, roll-over, and winch operation. A separate circuit provides Vickers hydraulic power steering.



ASK FOR NEW BULLETIN M-5101

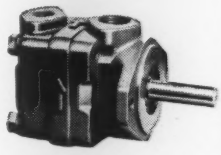
"Vickers Hydraulics" on materials handling equipment denotes superiority in two ways: First, the maker has obtained the benefits of the best in hydraulic equipment. Second, such care in the selection of hydraulic units generally denotes good design and careful construction throughout.

Among the important advantages of Vickers Hydraulics are simplicity of hydraulic design and of installation, complete flexibility of control, inherent protection against abuse and overloading. For further information get in touch with your nearest Vickers Application Engineering office.



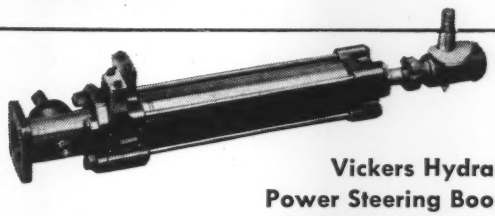
Vickers Pump for Hydraulic Power Steering

This pump is vane type, hydraulically balanced, and has automatic wear compensation. Series VT4 has integral volume control and relief valves and oil reservoir.



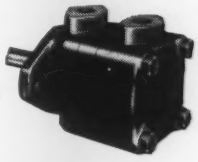
Vickers Pumps (Single and Double)

Balanced vane type pumps that automatically maintain optimum radial and axial running clearances over complete pressure range and throughout pump life. The result is long life and maintained high efficiency.



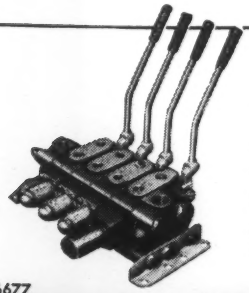
Vickers Hydraulic Power Steering Booster

Provides effortless, positive and shockless steering. With the touch of only a finger, driver can steer the heaviest vehicle on or off the road. Fatigue is reduced and driver efficiency increased.



Vickers Hydraulic Motors

Balanced vane type with exclusive "rocking beam" construction and automatic wear compensation. Variable horsepower (constant torque) characteristics; reversible and can be stalled under load without damage.



Vickers Multiple Unit Valves

Assemblies of standard interchangeable sections provide any desired combination of directional control functions. Exclusive porting arrangement provides smooth and selective inching control and accurate positioning.

6677

VICKERS Incorporated

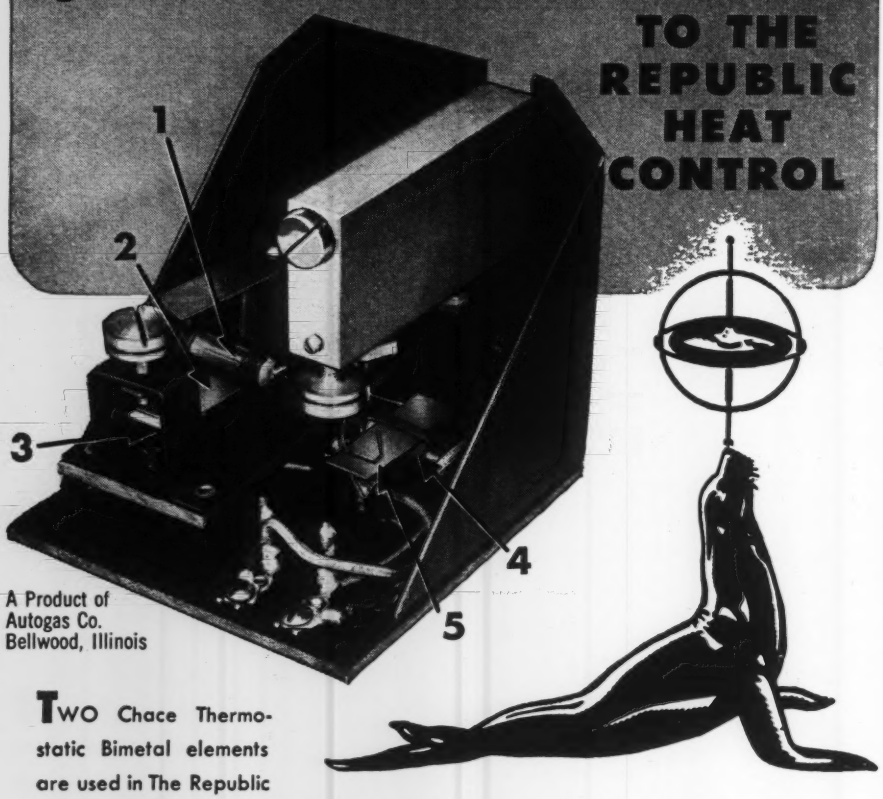
DIVISION OF THE SPERRY CORPORATION

1430 OAKMAN BLVD. • DETROIT 32, MICH.

Application Engineering Offices: ATLANTA • CHICAGO (Metropolitan) • CINCINNATI • CLEVELAND • DETROIT • HOUSTON LOS ANGELES (Metropolitan) NEW YORK (Metropolitan) • PHILADELPHIA (Metropolitan) • PITTSBURGH • ROCHESTER • ROCKFORD • SEATTLE • TULSA • WASHINGTON • WORCESTER

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

how CHACE THERMOSTATIC BIMETAL gives "GYROSCOPIC-BALANCE" TO THE REPUBLIC HEAT CONTROL



A Product of
Autogas Co.
Bellwood, Illinois

TWO Chace Thermostatic Bimetal elements are used in The Republic "Gyroscopic-Balance" system for controlling room temperatures to within 1/10 degree. Instead of full on and off heat supply at delayed intervals this unit "meters" out the heat to balance perfectly the heat losses as steadily as a spinning gyroscope stands on a seal's nose.

Coupled with a three-wire thermostat, the Republic unit provides not only on and off control but also high and low flame in steps to balance heating losses accurately. The system does not need the necessary delay interval built into two-wire thermostats to prevent cycling.

Republic's system permits a floating contact in the thermostat which is sensitive to 1/10 degree and immediate action. Contact at the thermostat causes resistor (1) to heat, with a resultant bending of bimetal element (2) and, after a moment, the closing of contacts (3). This circuit opens the fuel valve to low flame. The contacts influenced by a magnetic field cannot open, thus preventing cycling.

The second set of contacts in the thermostat, sensitive to 1 to 1½ degrees, causes resistor (4) to heat, bending bimetal (5). This action closes a small gas valve permitting the burner to go to high flame. Thus the rate of fuel burned changes constantly to match the varying heat recording in the room.

This is but one of the untold number of uses of Chace Thermostatic Bimetal. For a quarter of a century we have supplied leading manufacturers with thermostatic bimetals for use in products actuated by changes in temperature. If you are interested in such products, write today for our new 36-page booklet, "Successful Applications of Thermostatic Bimetal", which includes 10 pages of condensed engineering data.

IT BENDS WITH THE HEAT

W. M. CHACE CO.
Thermostatic Bimetal
1616 BEARD AVE., DETROIT 9, MICH.

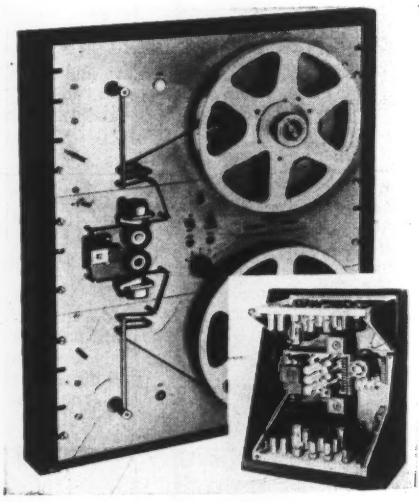
Engineering Equipment

galvanometer and voltage circuit closing keys, binding posts, plugs and lead connections. Three basic instruments have a total of 96 dc ranges from 5 ma full scale (lowest reading, 50 microamperes) to 60 amp in current, and 100 mv full scale (lowest reading, 1 mv) to 600 v full scale in voltage. These instruments are accurate to 0.5 per cent. Equipment can be combined in over 200 different ways for uses such as a high resistance voltmeter, a galvanometer or a potentiometer voltmeter; for measuring internal resistance and frequency; or for circuit testing. Made by **Sensitive Research Instrument Corp.**, 9 Elm Ave., Mount Vernon, N. Y.

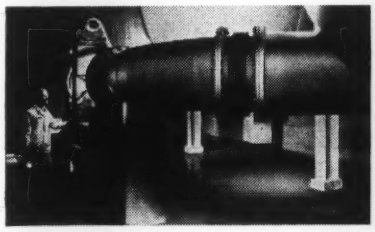
For more data circle MD-125, Page 223

Tape Recorder-Transcriber

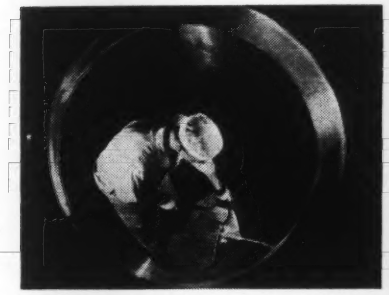
Model 902 magnetic digital tape recorder and transcriber starts and stops in 5 milliseconds; maximum tape speed is 60 in. per second. Tape width to ⅝-in. permits recording of as many as eight channels of information simultaneously. Various tape width and speed combinations are available, using 8 and 10½-in. reels with 1200 and 2400-ft tape capacities, respectively. Power required is 400 w at 115 v, 60 cycles. Instrument records information as it is produced, continuously or intermittently, fast or slow, and stores it indefinitely. Applications include storage of telemetered data



HEAT RESISTANCE: ENDURO can handle gases from full scale thermal jet engines, reciprocating engines, turbines, burners and other equipment tested in simulated high altitude conditions.



CORROSION-RESISTANCE: This is one of ENDURO's best known qualities. Installations of various types over the past thirty years offer visible proof that ENDURO stands up under some of the toughest corrosive conditions.



CLEANABILITY: ENDURO's high resistance to radioactive matter makes it a choice for equipment where this material is used. The answer is its smooth finish which offers little surface to which particles can cling.

Here's how they're using some of Enduro's properties

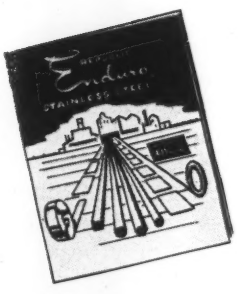
Aviation design engineers have long used ENDURO Stainless Steel for its high strength-to-weight ratio. Its resistance to high as well as sub-zero temperatures.

Now, designers in other fields are discovering new uses for ENDURO. For its remarkable ease of cleaning. For its satin luster. For its high resistance to rust and corrosion.

Management likes ENDURO, too. It can be fabricated profitably. And it gives extra sales features to products which might otherwise be lost in the shuffle.

No other commercial metal offers such a unique combination of physical and chemical properties as ENDURO Stainless Steel, the metal of 10,000 uses. Republic will be glad to help you use it... profitably. Write to:

REPUBLIC STEEL CORPORATION
Alloy Steel Division • *Massillon, Ohio*
GENERAL OFFICES • **CLEVELAND 1, OHIO**
Export Department: Chrysler Building, New York 17, N. Y.



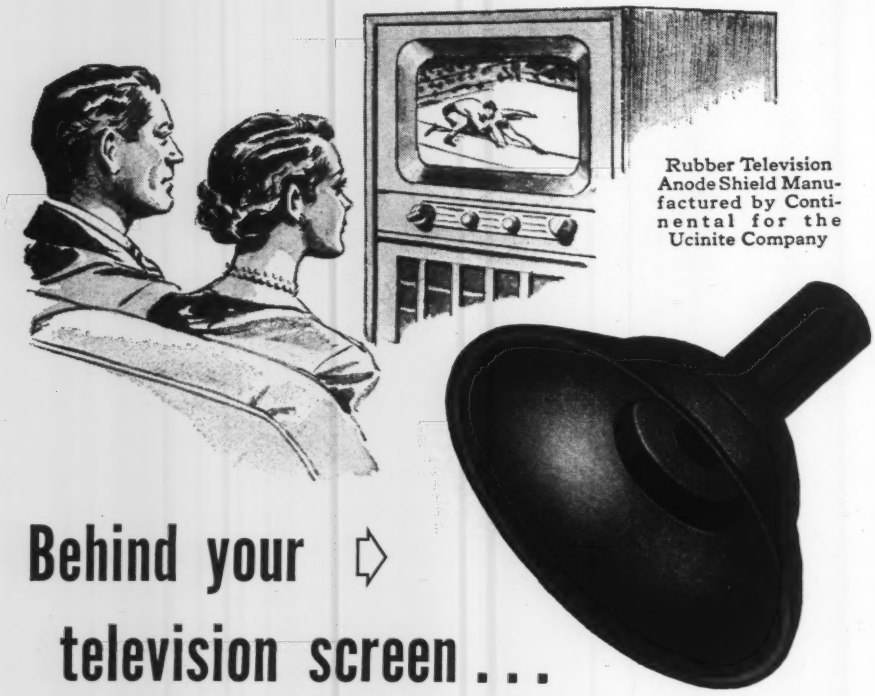
FREE

This 36-page booklet gives properties, fabricating and joining methods, care and finishing of ENDURO Stainless Steels. Write for it. Ask for ADV. 561.

REPUBLIC
ENDURO STAINLESS STEEL

REPUBLIC STEEL ®

Other Republic Products include Carbon and Alloy Steels — Titanium — Pipe, Sheets, Strip, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing



Rubber Television Anode Shield Manufactured by Continental for the Ucinite Company

Behind your television screen . . .

Continental Rubber gets into the act

In the unseen act behind your television screen, a small cup-shaped rubber shield plays an important role. This shield fits over the anode on the side of the tube. Its function is to "seal in" high voltage current and thus prevent surface discharges that cause picture distortion.

Ordinary rubber compounds, of course, can't fill the bill. *This* rubber part must have exceptional dielectric properties and unusual stability under sustained heat. It must resist the deteriorating effects of ozone created by electrical discharges. In addition, the rubber shield must be precision molded to insure proper seating against the side of the television tube.

Continental engineers, working closely with Ucinite Company engineers, have met these exacting requirements. This technical cooperation typifies the service in rubber offered by Continental.

When *you* need better engineered rubber parts, why not enlist the service of specialists in molded and extruded rubber?

LET US SEND YOU THIS CATALOG

This new engineering catalog lists hundreds of standard grommets, bushings, rings and extruded shapes. It will be a valuable addition to your working file. Send for your copy today or . . .

See our Catalog in Sweet's File for Product Designers

MANUFACTURERS SINCE 1903

CONTINENTAL RUBBER WORKS

1984 LIBERTY BOULEVARD • ERIE 6, PENNSYLVANIA

BRANCHES

Baltimore, Md.	Cleveland, Ohio	Kansas City, Mo.	Pittsburgh, Pa.
Boston, Mass.	Dayton, Ohio	Los Angeles, Calif.	Rochester, N. Y.
Buffalo, N. Y.	Detroit, Mich.	Memphis, Tenn.	St. Louis, Mo.
Chicago, Ill.	Hartford, Conn.	New York, N. Y.	San Francisco, Calif.
Cincinnati, Ohio	Indianapolis, Ind.	Philadelphia, Pa.	Syracuse, N. Y.

for subsequent use in computers and collection of information pertaining to high-speed industrial processes for subsequent conversion to control information for automation. Made by **Potter Instrument Co. Inc.**, 115 Cutter Mill Rd., Great Neck, N. Y.

For more data circle MD-126, Page 223

Electronic Counter

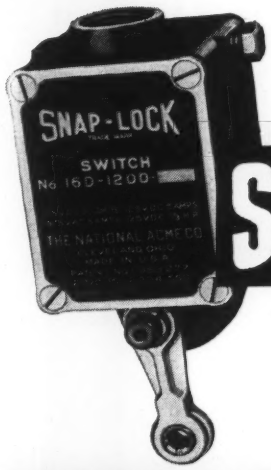
Utilizing cold cathode electronic circuitry throughout, Model RC direct reading counter operates at speeds up to 10,000 counts per minute and has a total counting capacity of 9,999,999. It consists

of an electronic decimal unit preceding a six-digit electro-magnetic register. Instrument operates with accuracy of ± 0 and is unaffected by line voltage variations and fluctuations. Power requirement is 35 w at 115 v, 60 cycles. Size is 18½ x 8 x 8¼ in.; weight, 20 lb. Made by **Haledy Electronics Co.**, 57 William St., New York 5, N. Y.

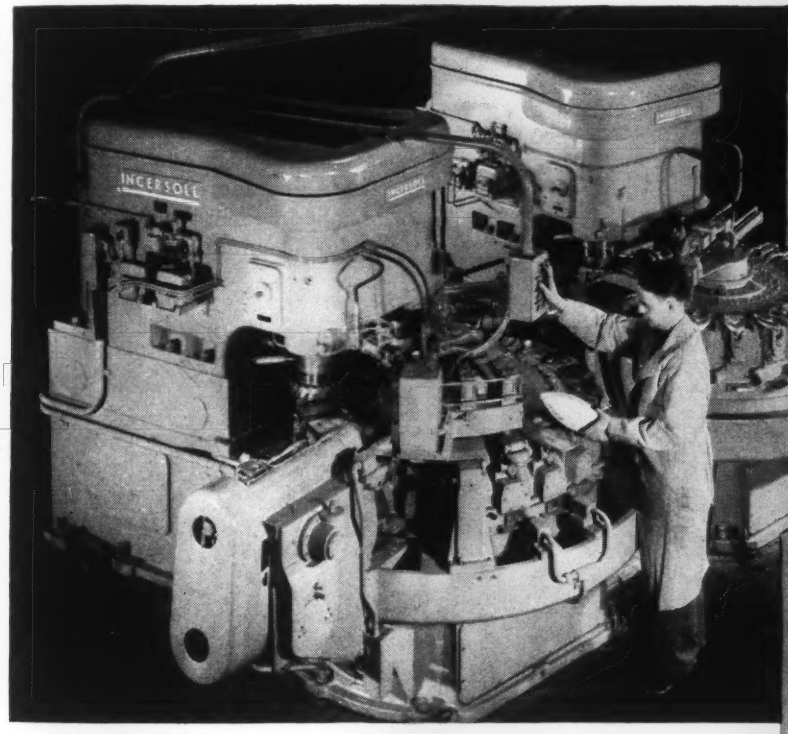
For more data circle MD-127, Page 223

Glass Cloth

Made by impregnating cloth woven from continuous glass fibers with a blend of Paraplex polyester resins, this photo template material has good dimensional stability and transparency. A glass cloth template can be copied without distortion on a contact printing table in which a vacuum holds the original firmly against the copy. Silver emulsions, Diazo or any of the usual sensitizing materials may be used. Drawings made on metal plates can be copied rapidly on the sensitized glass cloth by reflex print-



SNAP-LOCK TRADE MARK plays a vital part in new plant-automation plans

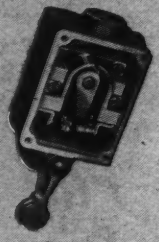


TWO COMPARTMENTS

sealed off—self-protected

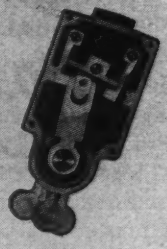
ELECTRICAL SIDE

Accessible wiring connections, self wiping coin silver contacts, no arcing, heavy insulation throughout, oil and dust resistant case. Single pole, double break, double throw —positive lock in ON or OFF position.



MECHANICAL SIDE

Hardened steel parts, strong spring, rugged, compact construction, wide choice of operating levers. Snap-Lock is guaranteed mechanically and electrically for any normal circuit application.



Snap-Lock is the heavy duty limit switch—quick acting, positive, dependable—built *by* machine tool builders *for* machine tool builders.

In the 15 years since we first designed Snap-Lock to meet our own machine tool needs, it has been adopted as the standard switch equipment by 4 out of 5 of all builders of precision operated machine tools. Hundreds of users of other types of equipment also specify Snap-Locks—where control is vital, where lasting and service-free life is more important than mere price.

If you have a switch problem, choose from the wide variety of Snap-Lock standard types with regular or special mountings or, if you need a special application, let our engineers help you design Snap-Lock into your product.

Ask for Engineering Bulletin EM-51

INGERSOLL says:

"for this special model, again we rely on 13 Snap-Lock switches to insure correct sequencing of all 6 operations for automatic milling of tops, bottoms and sides of sole plates for electric flat irons at 1000 per hour-- fastest rate ever attained."

The Ingersoll Milling Machine Co. at Rockford, Ill., top flight builders of precision automatic milling, boring and drilling machines, have for years standardized on Snap-Lock limit switches.

ELECTRICAL MANUFACTURING DIVISION

The NATIONAL ACME COMPANY

170 EAST 131st STREET • CLEVELAND 8, OHIO

ACME-GRIDLEY
BAR and CHUCKING AUTOMATICS
1-4-6 and 8 Spindle • Hydraulic Thread Rolling Machines • Automatic Threading Dies and Taps • Limit, Motor Starter and Control Station Switches • Solenoids • Contract Manufacturing

DIAPHRAGM OPERATED CONTROL VALVE WITH

Full Port Diameter

AND

4-Position Indexing

TYPE D-53

- Also applicable wherever desireable to control line flow by use of independent pressure on the diaphragm. Type D-53 is finding wide acceptance in substitution for expensive Solenoid Valves.
- Full port means high capacity. All bronze housing. Renewable chrome plated valve seat and composition seat disc. Neoprene nylon diaphragm. Also available with adjustable maximum and/or minimum flow limit stops.
- **For additional information on Type D-53, and other new automatic valves in the Cash-Acme line, write our Engineering Department at the address below. To avoid delay, please include a brief outline of your pressure conditions and requirements.**

This new pressure operated valve is offered in two basic types . . . either normally open and *closed* by diaphragm pressure or normally closed, and *opened* by diaphragm pressure. Typical use is on water cooled compressors.

Type D-53 may be used to handle water, air, oil or any non-corrosive fluids. Maximum body pressure 250 psig; diaphragm pressure 300 psig. For maximum hookup flexibility, the diaphragm pressure connection on this new Cash Acme valve may be indexed to any of the following four positions:

1. Over inlet
2. Over Outlet
3. Right Side
4. Left Side

CASH ACME

A. W. CASH VALVE MANUFACTURING CORP.

6613 E. Wabash Avenue Decatur, Illinois

The Complete Cash-Acme Line Includes Pressure Reducing and Regulating Valves, Relief Valves, Back Pressure Valves, Vacuum Regulators and Vacuum Breakers, Differential Pressure Regulators, Strainers, Diaphragm Control Valves.

I—1-54

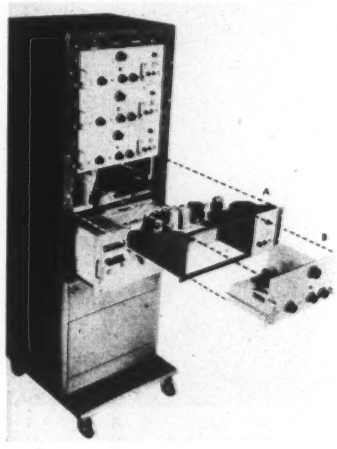
Engineering Equipment

ing. Processed by Swedlow Plastics Co. with resins developed by Rohm & Haas Co., the material is made in widths up to 60 in. in cut sheets or in 100-yd or longer rolls. It is normally furnished in 5½ mil thickness but is available in thicknesses down to 2 mils. Developed by **Tru-Scale Engineering Supply Co.**, 254 Laura Ave., Wichita, Kans.

For more data circle MD-128, Page 223

Recording System

Four-channel oscillographic recording system combines interchangeable plug-in elements which provide graphic registration of most phenomena, individually or up to four simultaneously, within



the frequency range of 0 to 100 cycles per second. Model 150 consists of a vertical cabinet containing the recorder assembly and a built-in driver amplifier and power supply unit (A) for each of the four channels. The preamplifier (B) required for a specific application is plugged into the appropriate channel. Changing the preamplifier adapts the system to recording stress, strain, pressure, displacement, thickness, velocity, acceleration, current, voltage, temperature, torque, light, flow, force, load, position, revolutions per minute, radiation and tension. Standard preamplifiers available include ac-dc, carrier, dc coupling, servo monitor, log-audio and low level. Blank assemblies are also

Where will you put this remarkable plastic to work?

No matter what you make, BAKELITE Polyethylene offers you properties worth investigating. Here's a material that remains flexible even at below-zero temperatures . . . with excellent dielectric properties, high impact strength. It's highly chemical resistant, and lightest in weight of all plastics. It can be fabricated by molding, blow molding, extrusion . . . by every process used with plastics. And BAKELITE Polyethylene is in an increasingly favorable position for your planning—with increasing supplies at decreased prices, *59 percent reduction* since 1943. For a broad picture of how you may benefit send for your free copy of BAKELITE Polyethylene. Write Dept. UR-52.

Polyethylene first made possible insulation for high-frequency radar equipment. Then, TV lead-in, wire and cable insulation benefited by its unique properties.

Came the polyethylene squeeze bottle—revolutionizing an industry, supercharging marketing for now over 2,000 products requiring over 75,000,000 bottles.

And more and more pounds of polyethylene go into lightweight, chemical-resistant pipe for farm and industrial water supplies, chemical and medical tubing.

Safer chemical carboys and acid bottles of polyethylene are unbreakable; their light weight brings substantial savings on shipping and handling charges.

Polyethylene film . . . stronger, attractive, easily sealed . . . packages sales appeal and protection around hundreds of items from fresh and frozen foods to shirts.

From moldings to laminations with other materials, the remarkable properties of polyethylene are making products that look better, sell better, and work better in every industry.

BAKELITE Polyethylene

TRADE-MARK

BAKELITE COMPANY, *A Division of Union Carbide and Carbon Corporation* UCC 30 East 42nd Street, New York 17, N.Y.

In Canada: Bakelite Company, Division of Union Carbide Canada Limited, Belleville, Ontario

here's *automation* at work

with a CAMBRIDGE

WOVEN WIRE CONVEYOR BELT!

Cut corn is blanched, cooled and frozen on Cambridge Woven Wire Conveyor Belts. Entire operation is *continuous and automatic*, requires no manual handling until discharge from freezing tunnel.

Regardless of whether your process temperatures range from sub-zero to as high as 2100° F . . . whether you use water rinses, acid pickles or other corrosive processes . . . a Cambridge woven wire belt can help you cut manufacturing costs by contributing to automation . . . continuous, automatic production.

Cambridge belts are all metal and can be woven from any metal or alloy. Thus, they are impervious to damage from heat, cold or corrosive conditions. That's why they can be used to process parts or materials while moving from one location to another.

Because of their open mesh construction they permit free circulation of process atmospheres, free drainage of process solutions. They are available in a wide range of specifications for carrying light or heavy loads, large or small parts.

Special raised edges or cross-mounted cleats to hold your product on the belt during flat or inclined movement are easily supplied.

Get the full story—FREE! Learn how Cambridge Woven Wire Conveyor Belts can help you boost efficiency by continuous, automatic production . . . *automation!* Write today for your copy of this manual of belt applications. It's the most complete text available.

Or, for immediate advice, call in your Cambridge Field Engineer. You can rely on him to make just the right recommendation for you. Look under "Belting-Mechanical" in your classified phone book, or write direct.

The Cambridge Wire Cloth Company

WIRE CLOTH | METAL CONVEYOR BELTS | SPECIAL METAL FABRICATIONS

DEPARTMENT N
CAMBRIDGE 4,
MARYLAND

OFFICES IN LEADING INDUSTRIAL AREAS

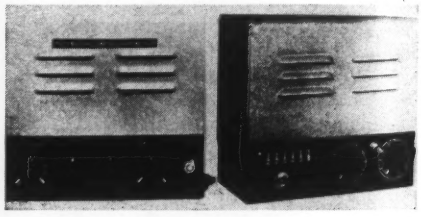
Engineering Equipment

available. Made by **Sanborn Co.**, Industrial Div., 195 Massachusetts Ave., Cambridge 39, Mass.

For more data circle MD-129, Page 223

Repeat Cycle Timers

Two fully enclosed repeat cycle electronic timers are stable and accurate during normal changes of line voltage and temperature. They are housed in 9 x 10 x 5-in. steel cabinets with external settings for the range of the instruments. Power supply is 105 to 120 v ac; dc models are also available. Both models have relays



with single-pole, double-throw contacts; model 2 is rated at 5 amp and model 3, at 7 amp at 115 v ac. On-cycles range from 0.2 to 150 seconds; off-cycles, from 0.1 to 900 seconds in model 2. Both on and off-cycles of model 3 range from 0.01 to 6 seconds. Timers are made by **G. C. Wilson & Co.**, 1950 Eighth Ave., Huntington, W. Va.

For more data circle MD-130, Page 223

Translucent Contact Paper

High-speed Diazo or blueprint reproduction is afforded by Kodagraph Contact Paper Translucent, an extra-translucent and durable contact paper. Photographic lines on paper can be erased with ordinary pencil eraser after paper is moistened slightly. Paper employs Kodagraph Contact emulsion which produces clean, sharp lines and is designed for processing in same manner as all Kodagraph contact papers. New paper is available in all standard sizes. Made by **Eastman Kodak Co.**, Rochester 4, N. Y.

For more data circle MD-131, Page 223

THE ENGINEER'S

Library

Recent Books

Stress-Concentration Design Factors. *By R. E. Peterson, manager of mechanics dept., Westinghouse Research Lab.;* 165 *pages,* 9 *by* 11 *inches, cloth covered, wirebound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, $8.50 *postpaid.*

Arranged in both content and physical details as a handbook for design, this manual brings together data in consistent form on stress-concentration factors for many typical design situations.

The principal purpose of the volume is to aid designers in obtaining greater accuracy in strength calculations and thereby, fewer failures and better-balanced designs. It is not a textbook, although sufficient fundamental and background information is given to acquaint the reader with the purpose of the stress-concentration concept in design and to provide a basis for more detailed study.

Scope of the manual is suggested by the following chief indexing tabs: grooves, fillets, holes, keyways, gear teeth, T-heads, curved bars, helical springs, and rotating disks. Design data over the full parameter ranges likely to be encountered are presented in full-page graphical form. Charts in certain of the mentioned subject areas were published in MACHINE DESIGN during 1951.

♦

Principles of Transistor Circuits. *Edited by Richard F. Shea;* 565 *pages,* 5¾ *by* 9 *inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, $11.00 *postpaid.*

This book is coauthored by nine members of the engineering staff of the General Electric electronics laboratory in Syracuse, New York. After a brief introduction to semi-

To seal glass safely, use this cork-and-rubber tape

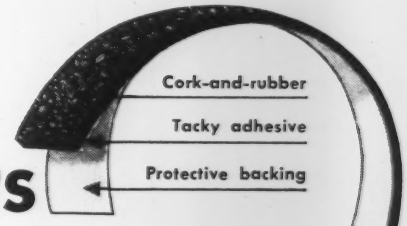
To keep glass breakage down, many makers of automatic venders, parking meters, and similar equipment use Armstrong's resilient DK-153 Tape to seal their "windows."

DK-153 provides a springy cork-and-rubber cushion that absorbs shocks and vibrations and prevents rattles while it keeps out dust and moisture.

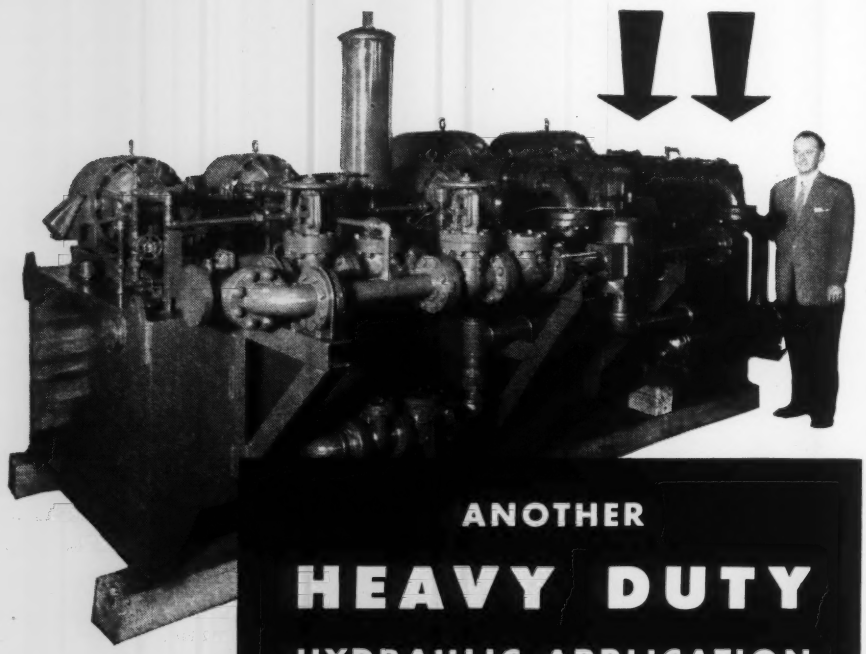
A pressure-sensitive adhesive on the back makes DK-153 Tape easy to apply. You just peel off the cloth backing and press into place. It sticks instantly to any clean, dry surface.

DK-153 Tape is also used for packing fragile parts to prevent breakage and scratching in shipment, as an anti-squeak material in fenders and bus bodies, and as an anti-skid base for phones and office equipment.

You can get DK-153 in several widths and thicknesses, in sheets, ribbons, rolls, and die-cut shapes. For samples and more information, write on your letterhead to Armstrong Cork Company, Industrial Division, 7304 Dean St., Lancaster, Pa. Available for export.



ARMSTRONG'S DK-153 TAPE



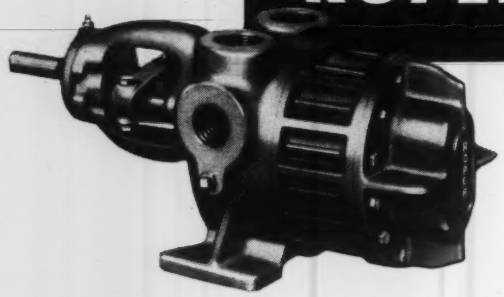
ANOTHER

HEAVY DUTY

HYDRAULIC APPLICATION

SOLVED WITH

ROPER PUMPS



Series F Pump . . . for pumping clean liquids of all kinds. Pressures to 300 P.S.I. — sizes 1-300 G.P.M.

SPECIAL HYDRAULIC APPLICATION USING STANDARD ROPER SERIES "F" PUMPS

THE PROBLEM: Develop a centralized hydraulic power unit to operate large elevators and hydraulic pushers through a continuous heat treating and annealing furnace in a steel mill.

THE ANSWER: The enormous hydraulic unit shown; as designed and built by Weinman Pump and Supply Co. of Pittsburgh.

This is but one of many special units developed by Weinman. And, here again, Roper Pumps were selected as integral parts of the complicated power system. Roper Series F Pumps are particularly adaptable to this and other applications because of their four-port design for ease of installation and their unusual *dependability* and *long life.*

You, too, can capitalize on improved performance records by including Ropers as original equipment. Our men in the field will be glad to give you all the assistance you need in the selection of the most suitable size pump for the job.

ROPER
Rotary Pumps

SEND FOR CATALOG 954

Features the complete Roper line

GEO. D. ROPER CORPORATION
244 Blackhawk Park Ave., Rockford, Illinois

The Engineer's Library

conductor physics and various types of transistors, the material is divided mainly into three parts covering essentially low-frequency, high-frequency, and large-signal nonlinear applications. In each section the same general organization is followed: presentation and analysis of equivalent circuits, analysis of the mathematical relationships, and development of applicable circuits. The subject matter is liberally illustrated. Many problems and an extensive bibliography are included at the end of each chapter.

♦

Inventions and Their Protection. *By George V. Woodling, lecturer at law, Western Reserve University; 509 pages, 6 by 9 inches, clothbound; published by and available from Clark Boardman Co. Ltd., New York, N. Y. or Matthew Bender & Co. Inc., Albany, N. Y.,* $10.00.

The primary objective of this book is to arm engineers and designers with a practical understanding of how and why a patent on an invention gives it legal protection and enhances its economic value. Principles of patent law procedures are discussed to provide a more realistic and accurate concept of the patent system. Some of the material has been utilized to form the basis for a series of articles which appeared over several years in MACHINE DESIGN.

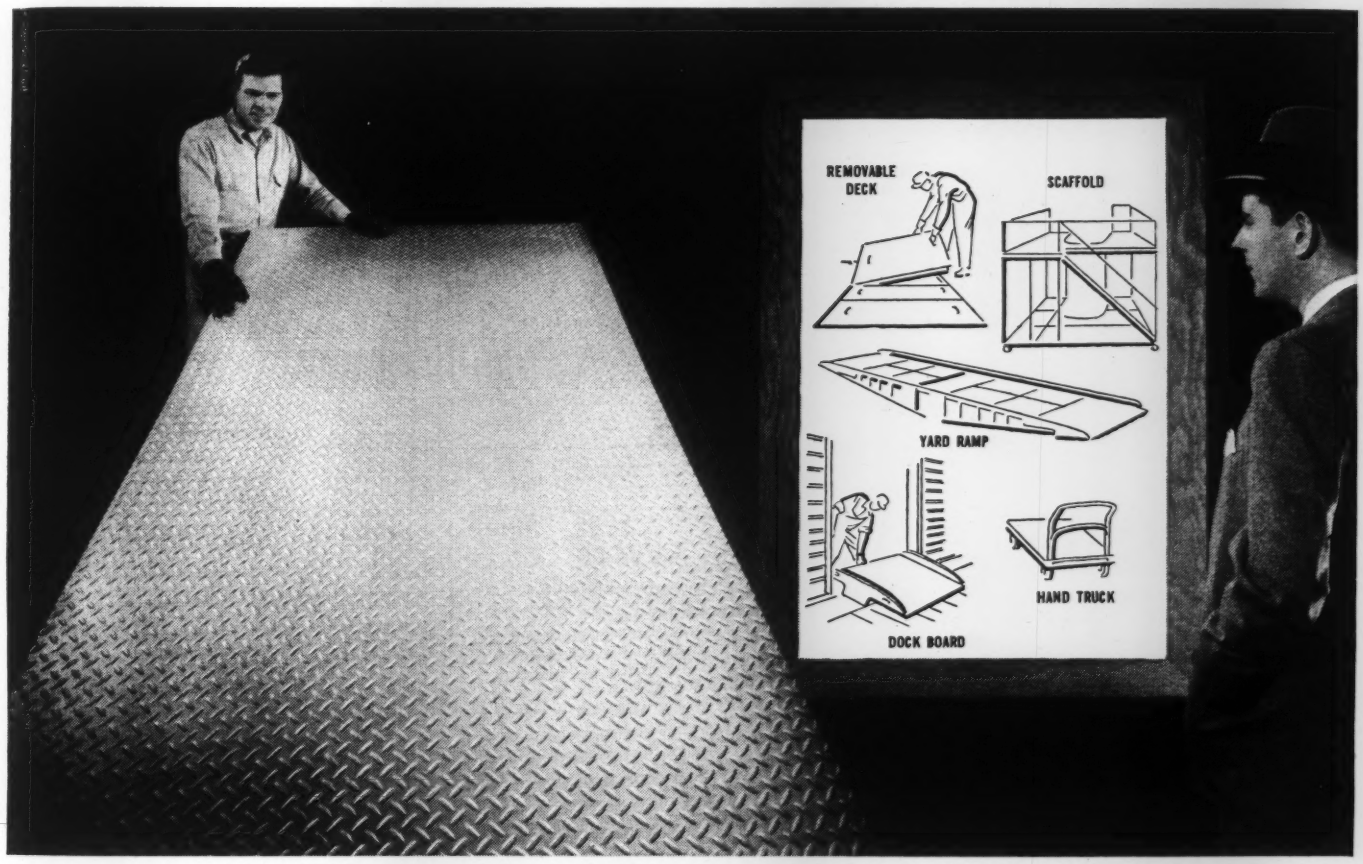
Two major revisions are made in this second edition: (1) an amplified text to include a wider range of patent problems and (2) a detailed discussion of the *New Patent Codification Act* which became effective January 1, 1953, including changes in and effects on present and future inventions.

♦

Manual of Mathematics. 334 *pages, multiple ring binder with four* 3¾ *by* 6¾*-inch paperbound sections; available from Lefax Publishers, 9th & Sansom St., Philadelphia 7, Pa.,* $2.25.

This pocket-size data book contains four tab-indexed sections entitled mathematical reviews, logi-

DOW



Take a new look at magnesium . . . *wherever equipment must be lifted or moved. Today, more than ever before, magnesium can help you design for greater savings in weight, greater economy in fabricating costs.*

LIGHTWEIGHT MAGNESIUM TREAD PLATE

NOW AVAILABLE IN NEW SIZES AND GAUGES

Now, for the first time in the metals industry, you can get big, new sizes of lightweight Dow magnesium tread plate.

For example, Dow magnesium tread plate made to the famous "Inland" 4-way design is available in lengths up to 16 feet . . . in widths up to 6 feet . . . in thicknesses up to 2 inches. This is important news for every designer.

These larger sizes mean faster, more economical fabrication *plus* new design opportunities in the field of materials handling. Look to magnesium wherever weight and motion are important use factors.

There is a place for tread plate made of magnesium, *the world's lightest structural metal*, almost everywhere, in every plant, every industry.

For further information about Dow magnesium tread plate, fill in the coupon below and mail it today. THE DOW CHEMICAL COMPANY, Midland, Michigan.

Send for new booklet about DOW MAGNESIUM TREAD PLATE

Contains new design opportunities using this *lightest* of all structural metals.

THE DOW CHEMICAL COMPANY, Dept. MA 321E, Midland, Michigan

Name_____

Company_____

Position_____

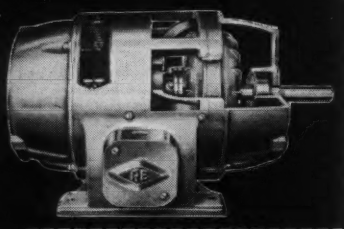
Address_____

City_____ State_____

you can depend on DOW MAGNESIUM DOW

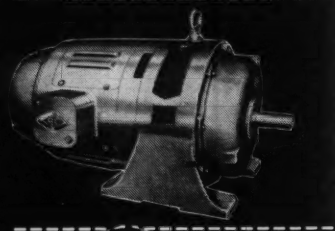
motor design problem?

...maybe one of these REULAND "specials" will solve it!



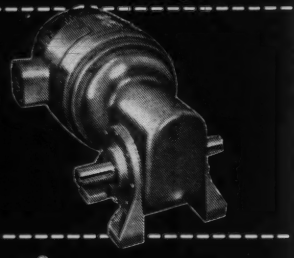
FLUID-SHAFT MOTOR

Motor with *internal* fluid coupling. Provides smooth load acceleration. More compact than separate motor and coupling. Assures *perfect alignment*. Will start heavier loads than standard motors of same horsepower. Used on cranes, conveyors, mixers, etc.



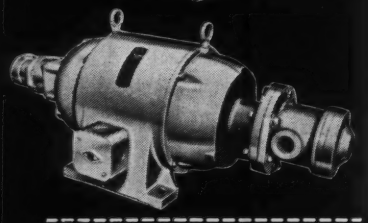
FLUID-SHAFT MOTOREDUCER

Consists of Reuland Fluid-Shaft motor and gear reducer as one compact unit. Converts the motor's conventional high speed into a slow speed, high torque output. Provides smooth starts. Prevents equipment jamming. Used on cranes, hoists, car pullers, etc.



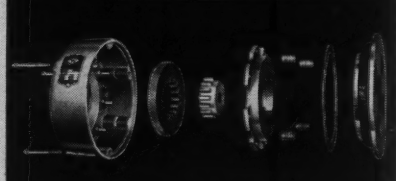
RIGHT-ANGLE MOTOREDUCER

Consists of Reuland motor and worm gear reducer. Provides unlimited mounting versatility. Permits use of 1 high speed and 2 slow speed power-take-off shafts, if desired. Ideal for designing into cramped quarters. Also available with Fluid-Shaft drive motor.



HYDRAULIC PUMP MOTOR

Special end bell flange permits direct, end bell mounting of all standard makes of pumps. Eliminates need for special mounting platforms. Assures absolutely perfect alignment with pump shaft. Available with mounting flange on one or both ends.



THROUGH-SHAFT MAGNETIC BRAKE

"Doughnut" type design allows extension of shaft entirely through brake. Permits use of TWO output shafts per motor. Can be mounted on the input or output shafts (or both) of Fluid-Shaft motors and motoreducers. Only 6 major parts . . . self adjusting . . . half usual length.

OVER 600 SPECIAL ELECTRIC MOTOR DESIGNS

Whatever your drive problems may be, there is a good chance that the Reuland "library of specials" contains a unit that is already tailored to your needs. Its availability will save you development work and put you in production faster.

Write today, outlining your particular problem. No obligation, of course.

RE **REULAND ELECTRIC COMPANY**

DISTRIBUTORS IN ALL PRINCIPAL CITIES

WESTERN DIVISION—ALHAMBRA, CALIFORNIA • EASTERN DIVISION—HOWELL, MICHIGAN

The Engineer's Library

rithms of numbers, natural trigonometric functions, and squares, cubes, square roots, etc. The mathematical reviews section contains over 200 equations on algebra, analytical geometry, trigonometry, and differential and integral calculus.

♦

Formulas for Stress and Strain. *By Raymond J. Roark, professor of mechanics, University of Wisconsin; 395 pages, 6 by 9 inches, clothbound; published by McGraw-Hill Book Co. Inc., New York; available from* MACHINE DESIGN, *$7.50 postpaid.*

A third edition, this well known handbook for designers brings together formulas, facts, tables and principles pertaining to mechanics of materials. Definitions, symbols, and units are briefly discussed in the first of the three major divisions of this volume. Part II deals with the behavior of bodies under stress along with principles and methods of analyzing stress and strain. The final part contains formulas and examples of simple and combined stresses useful in designing beams, flat plates, compression members, pressure vessels, pipes and bodies under direct bearing and shear stress, such as riveted joints. This part concludes with discussions of elastic stability, involving buckling of bars and plates, and dynamic and temperature stresses, including impact and sudden loading.

♦

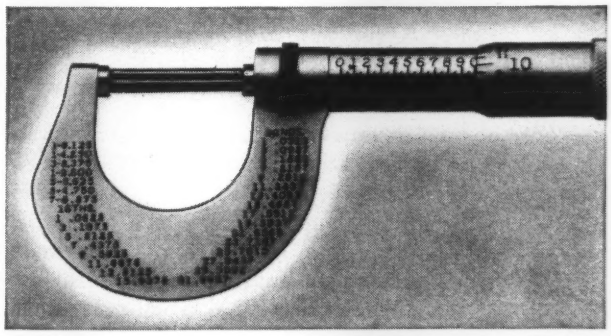
Applied Descriptive Geometry. *By Frank M. Warner, professor in engineering drawing, University of Washington; 255 pages, 6 by 9 inches, clothbound; published by McGraw-Hill Book Co. Inc.; available from* MACHINE DESIGN, *$4.00 postpaid.*

More than half of this fourth edition is devoted to fundamental principles of descriptive geometry and their application to engineering problems. A discussion is made on orthographic drawing; auxiliary views; point, line, and plane problems; revolution; concurrent noncoplanar forces; curved lines and surfaces; and intersection of sur-

*consistent quality

is as important in the pin as in the gear

To function effectively, a spring pin must drive easily into holes drilled to normal production tolerances, compressing as driven. To drive easily, hold firmly and fit flush, the pin —*every* pin—must meet the strict requirements of specifications such as those prepared by the SAE and the Military Services.



Since failure of a pin can be as costly as a failure of any other precision part, it is important to check the pins *you* buy for uniformity . . . uniformity of diameter and length, shear strength, hardness, insertion and removal forces, and recovery of diameter.

Rollpin has been tested many times—by many manufacturers—with a consistently high performance record. It has been widely recognized as the "quality" fastener of its type. In this case, quality can be—and should be—measured. We strongly urge that you test for quality when buying spring pins.

ELASTIC STOP NUT CORPORATION OF AMERICA

Dept. R28-44, Elastic Stop Nut Corporation of America
2330 Vauxhall Road, Union, New Jersey

Please send the following free fastening information:

☐ Rollpin samples
☐ Rollpin bulletin
☐ Here is a drawing of our product. What self-locking fastener would you suggest?

Name_____ Title_____

Firm_____

Street_____

City_____ Zone __ State_____

half

your job is done for you-

when you choose

WYCKOFF

COLD FINISHED STEELS

CARBON . . . ALLOY . . . LEADED

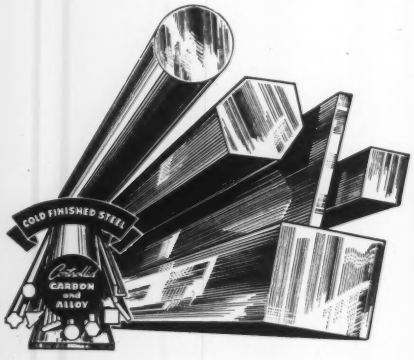
✓ ***Precision Dimensions***

✓ ***Precision Cross Section***

✓ ***Pre-finished Surface***

In this age of specialization nothing serves like the highly trained craftsmanship and concentrated experience of the specialist. WYCKOFF has specialized in fine quality cold finished steels . . . rounds, squares, hexagons, special shapes, wide flats and precision shafting. When it comes to cold finished steels in these classifications . . . nothing could be finer.

WYCKOFF STEEL PRODUCTS
Carbon and Alloy Steels
Turned and Polished Shafting
Turned and Ground Shafting
Wide Flats up to 12" x 2"
All types of furnace treated Steels



SPECIALISTS IN COLD FINISHED STEELS EXCLUSIVELY

WYCKOFF STEEL COMPANY

General Offices: Gateway Center · Pittsburgh 30, Pa.

Branch Offices in Principal Cities

Works: Ambridge, Pa. · Chicago, Ill. · Newark, N. J. · Putnam, Conn.

The Engineer's Library

faces. The remainder of the text is made up of practice problems to provide experience in the use of each principle previously covered.

New Codes

Low-Pressure Heating Boilers. *ASME Boiler and Pressure Vessel Code, Section IV; 35 pages, 8½ by 11 inches, paperbound; available from American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N. Y., $1.25 per copy.*

Part 1 of this code is applicable to steel-plate boilers; Part 2 covers cast-iron boilers. Rules are given for specifying materials, thicknesses of plates and tubes, joints, braced and stayed surfaces, boiler openings, supports, fittings and appliances, safety and relief valves, and hydrostatic tests.

Association Publications

Professional Engineers' Income and Salary Survey. *28 pages, 6 by 9 inches, paperbound; available from National Society of Professional Engineers, 1121 Fifteenth St., N.W., Washington 5, D. C., $0.50 each for NSPE members, $1.00 each for nonmembers.*

Data on the 1952 earnings of over 12,000 professional engineers are presented in this survey. Salaries and incomes are classified according to years of experience, branch of engineering, field of employment, type of work performed, grade, and geographical region.

Manufacturers' Publications

Heat Treating Aluminum. *122 pages, 5½ by 8½ inches, paperbound; available from Reynolds Metals Co., 2500 South Third St., Louisville 1, Ky., on company letterhead request.*

Principles and procedures for heat treating aluminum alloys are covered in this manual. Made up of three sections, the first contains a simplified discussion of aluminum metallurgy. Section II is a more complete presentation of met-

SPEED CONTROL

FOR

AUTOMATIC PRODUCTION

WITH

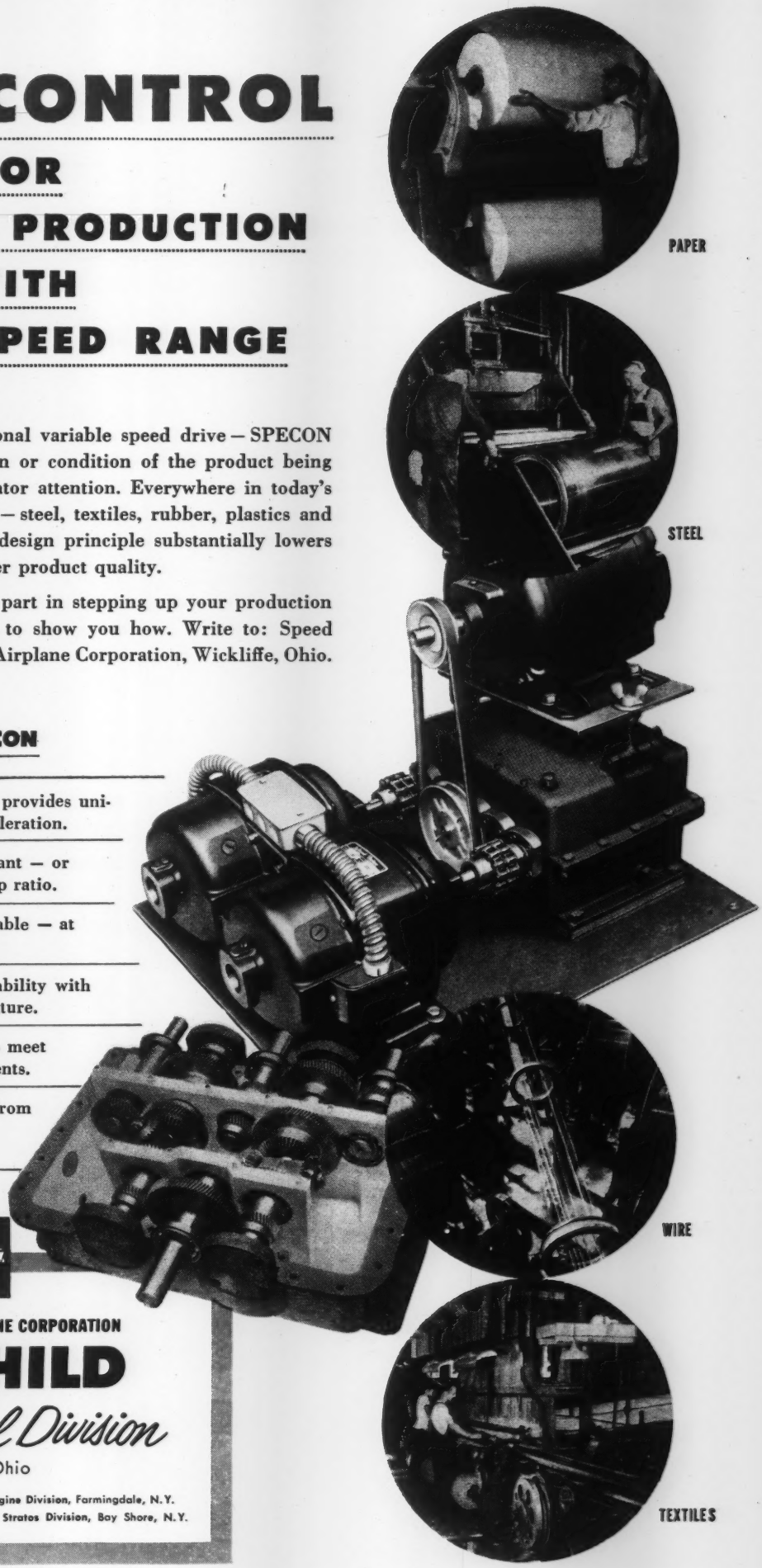
INFINITE SPEED RANGE

Completely unlike any conventional variable speed drive – SPECON controls production by the action or condition of the product being processed – with minimum operator attention. Everywhere in today's high speed industrial operations – steel, textiles, rubber, plastics and paper are but a few – this new design principle substantially lowers operating costs and assures higher product quality.

SPECON can play an important part in stepping up your production efficiency, too. We'll be pleased to show you how. Write to: Speed Control Div., Fairchild Engine & Airplane Corporation, Wickliffe, Ohio.

FEATURES OF SPECON

- ★ Instant automatic performance provides uniform uninterrupted speed acceleration.
- ★ Winding tension may be constant – or tapered for any desired build-up ratio.
- ★ Full torque continuously available – at low and zero speeds.
- ★ Unequalled safety and dependability with unique, positive adjustment feature.
- ★ Easy on-the-spot adjustments to meet changing production requirements.
- ★ Minimum maintenance results from standard interchangeable gears and motors.



ENGINE AND AIRPLANE CORPORATION

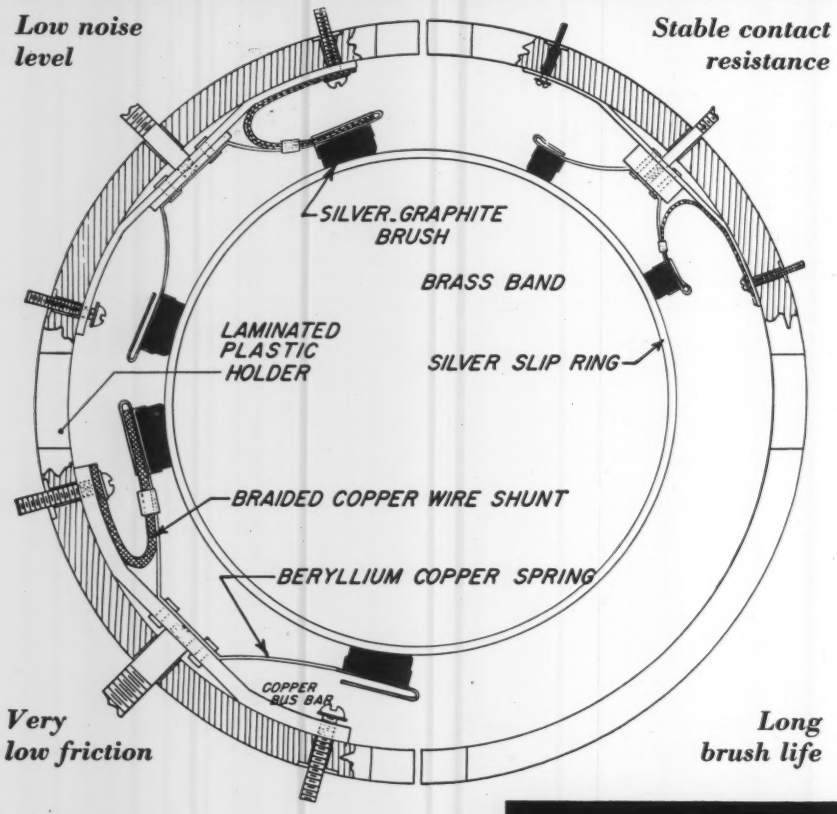
FAIRCHILD

Speed Control Division

Wickliffe, Ohio

Aircraft Division, Hagerstown, Maryland • Engine Division, Farmingdale, N.Y.
Guided Missiles Division, Wyandanch, N. Y. • Stratos Division, Bay Shore, N.Y.

Superior Designs Slip Ring Brush Assemblies for Electronic Use

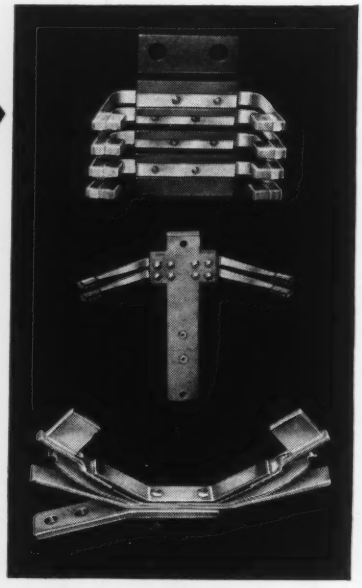


Superior Brushes Belong on Products Like These

The drawing above suggests how thoroughly the Superior staff works out every detail of a job. Superior will design and build any or all parts of a brush assembly, *OR* we will build to your design.

Write for our Catalog 6-DD. Letterhead request, please.

SUPERIOR CARBON PRODUCTS, INC.
9115 GEORGE AVENUE, CLEVELAND 5, OHIO



SCP SUPERIOR CARBON BRUSHES "Since 1919"

The Engineer's Library

allurgical details including wrought and cast products, heat-treatability, aging or precipitation hardening, heat-treating equipment a glossary of terms, and photomicrographs of various heat-treated structures. The last section presents tabular data on recommended heat-treating cycles and typical mechanical properties.

♦

Handbook of Electronic Circuits. *123 pages, 8½ by 11 inches, paperbound; published by and available from Government Service Div., RCA Service Co. Inc., Camden, N. J.,* $1.60 *per copy.*

Circuit diagrams and operation analyses are given for 77 basic circuits in this manual. These circuits provide the foundation from which many electronic devices can be designed, including power supplies, receivers, transmitters, limiters, discriminators, filters, control units, and radar and television equipment. Each circuit diagram is printed on an apron pull-out for convenient reference to the text material.

Government Publications

NACA Technical Series. *Each publication is 8 by 10½ inches, paperbound, side-stapled; copies available from National Advisory Committee for Aeronautics, 1924 F St., N.W., Washington 25, D. C.*

The following Technical Notes are available:

3053. **A New Method of Analyzing Extreme-Value Data**—88 pages.

3055. **Friction and Wear Investigation of Molybdenum Disulfide—Effect of Moisture**—28 pages.

3060. **Use of Electric Analogs for Calculation of Temperature Distribution of Cooled Turbine Blades**—116 pages.

3061. **Stresses around Rectangular Cutouts in Torsion Boxes**—71 pages.

3064. **Data on the Compressive Strength of Skin-Stringer Panels of Various Materials**—49 pages.

3090. **Investigation of Sandwich Construction Under Lateral and Axial Loads**—58 pages.

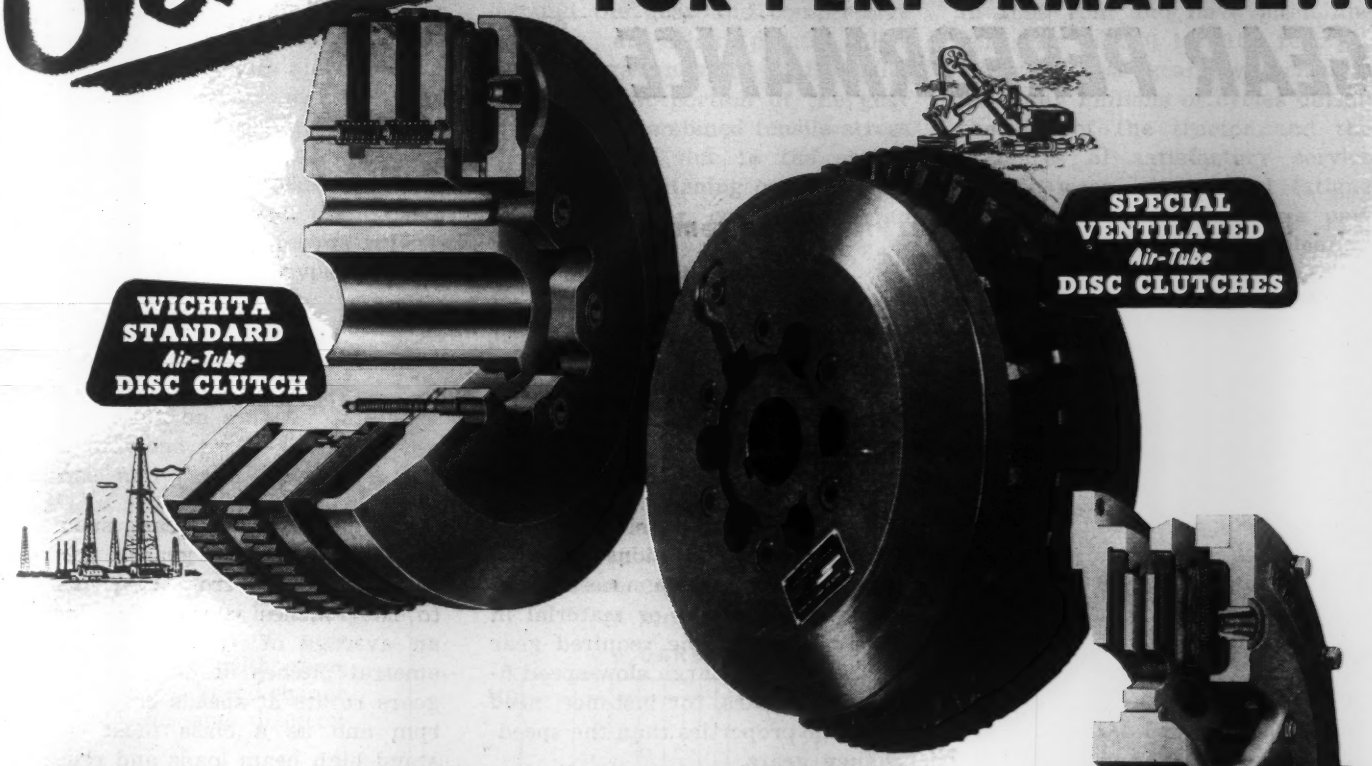
3094. **The Resistance to Air Blow of Porous Materials Suitable for Boundary-Layer-Control Applications Using Area Suction**—21 pages.

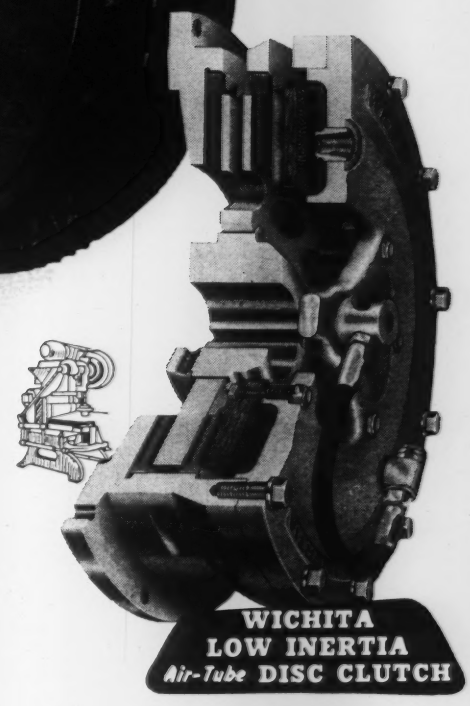
3101. **Study of Three-Dimensional Internal Flow Distribution Based on Measurements in a 48-Inch Radial-Inlet Centrifugal Impeller**—64 pages.

3111. **Friction and Wear Investigation of Molybdenum Disulfide.—Effects of Contaminants and Method of Application**—19 pages.

3117. **Lubricants of Reduced Flammability**—24 pages.

Sensational FOR PERFORMANCE...





WICHITA *Air-Tube* CLUTCHES

These three simple, compact, powerful, trouble-free Air-Tube friction clutches combine all the advantages inherent in air operation, such as: convenient remote control, small manual pressure required for full torque, smooth starting and quick disengagement.

They are engineered to give longer service at a lower operating cost because each requires very little maintenance. Many test runs of Wichita Clutches have exceeded 2½ million engagements and still no failures occurred. Such performance is proof of the sound engineering behind Wichita Clutches. Pick the Clutch *you* need for the job! *Call the nearest Wichita Engineer for complete detailed information.*

OTHER OUTSTANDING ADVANTAGES

- Safer Operation
- Cooler Running
- Minimum Slippage
- No Backlash
- Built in Standard and Low Inertia Types, All Positively Ventilated
- No Lubrication
- No Adjustments

WICHITA Falls

WICHITA FALLS, TEXAS, U. S. A.

WICHITA DISTRIBUTORS

Brehm-Lahner, Inc., Detroit, Michigan
L. H. Fremont, Cincinnati, Ohio
W. G. Kerr Company, Pittsburgh, Pa.
Smith-Keser & Co., (Main Office) West Hartford, Conn.
Smith-Keser & Co., Philadelphia 44, Pa.
Smith-Keser & Co., New York, N. Y.
Frank W. Yarline Co., Chicago, Ill.
Power Rig & Equipment Co., Inc., Long Beach, Calif
Robert R. King Co., Cleveland, Ohio
John C. Burge, Oklahoma City, Oklahoma

Ad 6DN

Evaluating GEAR PERFORMANCE

DESIGN ABSTRACTS

. . . in terms of cost and service requirements

By William E. Gustin and D. C. Smiley

John Deere Waterloo Tractor Works Deere Mfg. Co.

Waterloo, Iowa

MOST engineers and designers are at some time confronted with the problem of evaluating gears produced by a particular process. The usual information specified on the drawing of a gear, in an effort to guarantee a satisfactory result, includes dimensions, material, type of heat treatment, surface hardness and possibly core hardness.

A review of the existing literature on the subject of gears reveals vast quantities of information on steels, hardenability, metallurgical characteristics, and some information on fatigue life. Information is also available on many of the gear manufacturing processes such as carburizing, flame hardening, induction hardening etc. This information must be weighed carefully by the engineer confronted with the development of a complete transmission, for he soon realizes that gears within the same transmission have considerably different service conditions to withstand and it may be necessary to change the process or material in order to obtain the required gear performance. Large slow-speed final drive gears, for instance, need different properties than the speed-change gears.

The final measure of gear performance, as well as of any other mechanical component, depends upon the actual service life. In some cases this determination may take several years to obtain; therefore, it is important to be able to predict field performance by less time-consuming laboratory tests. Our experience indicates that gears cannot be properly evaluated by metallurgical properties such as surface hardness, core hardness, microstructure and chemistry.

Slow-speed Gears: Consider first the large slow-speed gears, such as final drive tractor gears. These gears may vary from 14¾ inches to 20¼ inches in diameter, have an average of 70 teeth and diametral pitches of 3½ to 5. The gears rotate at speeds of 10 to 30 rpm and as a class must withstand high beam loads and repeated impact loads. For a good many years these gears were made of a carburizing grade of alloy steel and were direct quenched. Through considerable development in heat treatment the gear tooth beam strength was increased from 30,000 pounds to 40,000 pounds. However, the demand for additional tractor power placed still greater requirements on these gears. As a means of reducing cost as well as increasing beam strength, an induction-hardened gear of 1050 steel was developed, *Fig.* 1.

Since the primary requisite of these gears is high beam strength

		STATIC TOOTH STRENGTH-LB.			COST SAVING PER PIECE USING 1050 STEEL INDUCTION HARDENED		
SIZE O.D.	NO. TEETH	8620 CARB. AND DIRECT QUENCHED	1050 INDUCTION HARDENED	PERCENT INCREASE	MATERIAL	LABOR	TOTAL
20 1/4	69	58,400	76,700	31	$2.34	$0.07	$2.41
17 1/2	68	38,500	57,100	48	1.98	0.11	2.09
14 7/8	72	37,700	47,600	26	1.17	0.30	1.47

Fig. 1 — Comparative cost and strength data for three different sizes of final-drive gears

and impact resistance, the induction-hardened gears are tempered at 500 F instead of the usual 360 F for carburized gears. The 500 F temper results in a slightly softer surface of approximately 54 Rockwell C. This lower surface hardness results in some distress; however, the total life of the tractor may require less than 5,000,000 cycles on these gears and since not all cycles will be at maximum load, the wear is negligible. Several years of field experience have indicated that the process is entirely satisfactory and that the laboratory beam strength test is sufficient to evaluate this type of gear.

Ring Gears: Another example of evaluating a gear manufacturing process pertains to a ring gear design shrunk on a cast iron spider. The previous process was to carburize and direct quench a ring gear of 8620 steel and then shrink it on a cast iron spider during the tempering operation. Distortion which took place during the quench caused the gear to be out of round before assembly. Installing the elliptical shape gear on a round spider caused tensile stresses in the root fillet at various locations around the gear and compressive stresses at other points. SR-4 strain gages mounted in the fillet over the flat portion of the gear indicated a combined tensile stress of 45,000 psi due to the shrink fit and straightening operations to make the gear conform to the spider.

By induction hardening the gear and decreasing the out-of-roundness error 40 per cent, the 45,000-psi tensile stress was reduced to 19,000 psi or a decrease of 55 per cent for the same amount of shrink fit. The service life of this gear, due to the induction-hardening process, was improved 100 per cent under full load conditions in the tractor on a transmission dynamometer.

Speed-change Gears: Another important type of transmission gear is the speed-change gear. These gears rotate at speeds of 300 to 1000 rpm and have pitch line velocities of 350 to 1100 feet per minute. These gears will encounter many millions of cycles during the life of the tractor and the measures of satisfactory service will be wear, pitting and fatigue life characteristics. In this particular application the problem of assembly and stability on an involute spline are also important.

The size of the first gear for consideration in this type is 4¾ inches in diameter, has 26 teeth and a diametral pitch of 6. For gears in this size group there are three general classifications of gear materials and processes as follows:

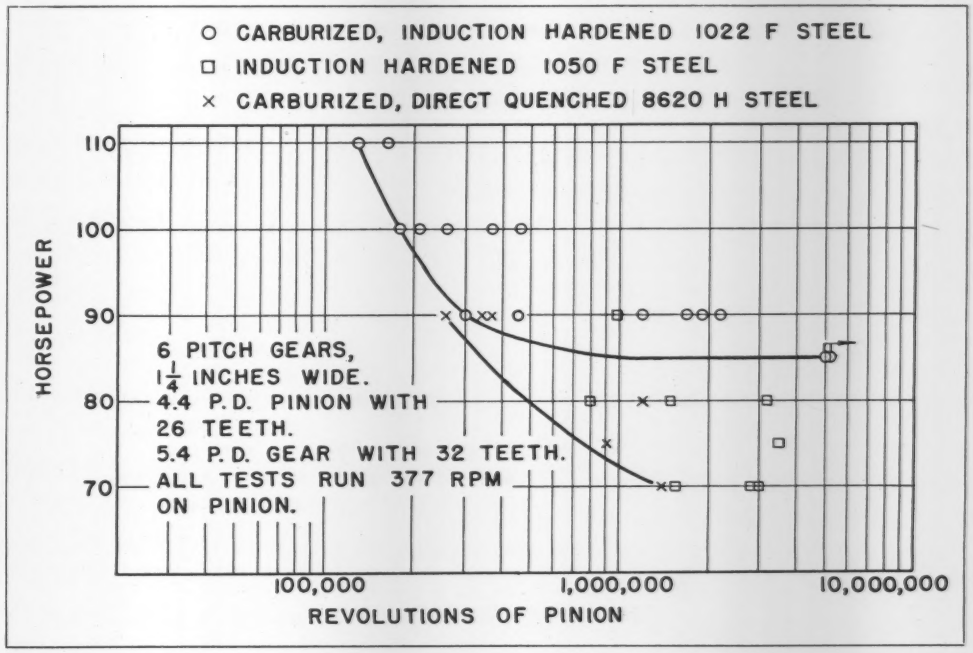
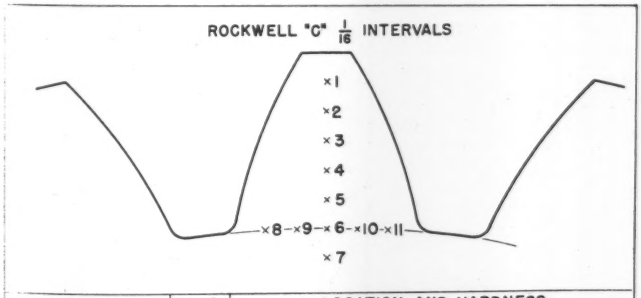


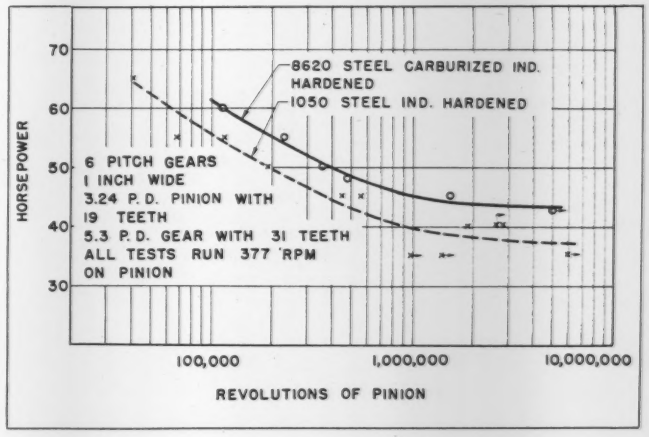
Fig. 2—Right — Plots of fatigue strength of gear teeth obtained with three medium-size speed-change gears of the same diameter

Fig. 3—Below—Comparison of tooth hardness characteristics

Fig. 4—Below right—Gear-tooth fatigue - strength curves obtained with two small speed-change gears of the same diameter



	CASE DEPTH	LOCATION AND HARDNESS											
		SURFACE	1	2	3	4	5	6	7	8	9	10	11
8620 CARB. AND DIRECT QUENCH	0.040	59	51	44	42	41	37	34	33	37	34	35	37
1022 CARB. AND IND. HARDEN	0.047	61	58	47	38	27	21	17	13	20	17	17	20
1050 IND. HARDEN		59	58	58	58	53	45	33	27	50	35	34	50



Design Abstracts

1. Alloy steel (8620) carburized and direct quenched.
2. Medium-carbon steel (1050) induction hardened.
3. Low-carbon steel (1022) carburized, air cooled and induction hardened.

The comparative fatigue strengths of gears in each of the above classifications are shown in *Fig.* 2. Here it can be seen that the 1022 steel design has the best endurance life of the three plus the advantage of a straight bore which can be obtained by rebroaching after hardening. Data for the curves were obtained by conducting laboratory tests in a four-square type of gear test machine which runs at the same speed as the gears operate in the tractor.

Generally speaking, the gears made of 1050 steel failed by pitting and breaking out a tooth. A gear made of the 1022 steel and operated for five-million cycles at an 85-hp load was in good condition when removed. The hardness characteristics for each of the three material classifications are shown in *Fig.* 3.

One of the most common laboratory tests conducted on gears is static tooth break-out strength. Static beam strengths of gears made of the 8620, 1050 and 1020 steels were found to be 25,000, 27,000, and 24,000 psi respectively. Obviously, from the standpoint of beam strength, the 1050 steel induction hardened appears to be the best; however, here is a case where static beam strength can be misleading.

The size of the second gear for consideration in the speed-change group is $3\frac{5}{8}$ inches in diameter has 19 teeth and a diametral pitch of 6. The two material classifications for this comparison are 8620 steel carburized and induction hardened and 1050 steel induction hardened. Fatigue curves for these two materials are shown in *Fig.* 4. Here again the 1050 steel shows a lower endurance limit, and the failures in the lower loads were of a pitting nature.

Gear Distortion: Distortion in the heat-treating process is always a problem of concern for the engineer working with speed-change gears. A sliding gear tends to creep in the direction where the spline bore is tightest. Dimensional tolerances on bore taper in direct-quenched gears are not always adequate; the bore of a gear made of alloy steel usually becomes smaller under the shifter groove during heat treatment while carbon steel tends to open up under the shifter-groove area. This spline bore distortion characteristic is shown on an exaggerated scale in *Fig.* 5. If the rebroaching operation is not used, 1050 steel induction hardened provides the best dimensional characteristics; however, the wearing qualities are not considered satisfactory for this type of service.

The distortion condition between various materials imposes severe problems when material substitutions make necessary the use of a steel having different characteristics. In fact boron steel, 80 B 20, did not react consistently the same as 8620 and the only practical way to use this material was to induction harden and rebroach the bore.

The major reason for using alloy steel originally rather than carbon steel in many gears has been to obtain better dimensional accuracy with the oil quench than was possible with carbon steel and caustic quench.

Cost Comparison: No evaluation of gear processes is complete without a cost comparison, *Fig.* 6. Obviously, where the gear is applicable, 1050 steel, induction hardened only, provides the cheapest process. We have, however, found very few applications in speed-change gears where the 1050 steel induction hardened is satisfactory from the standpoint of wear and pitting.

The major heat-treat equipment for the 8620 steel, when carburized and direct quenched, is the carburizer, while the 1022 steel requires the carburizer plus the induction-hardening equipment. This cost of the induction-hardening equipment must be offset by the reduction in price of material, by the improvement in bore dimensions, and by improvements in service life of the gears.

Simulated Service Tests: The four-square type of machine is an economical means of conducting accelerated tests by overloading the gears. It consists primarily of two gear boxes connected with parallel shafts. An adjustable coupling is provided in one shaft for changing the load and a load measuring device is incorporated in the other shaft. This may be a torque meter

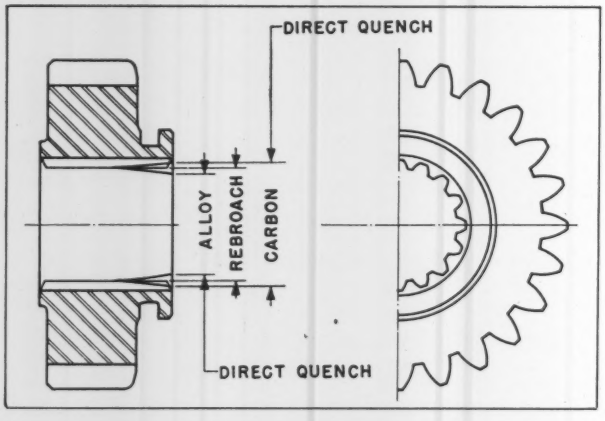
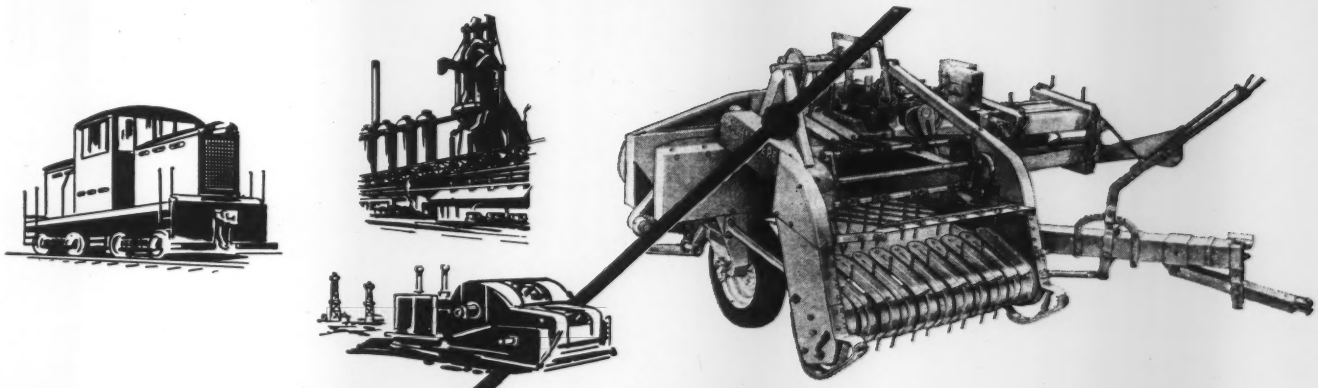


Fig. 5 — Typical spline bore distortion characteristics for speed - change gears

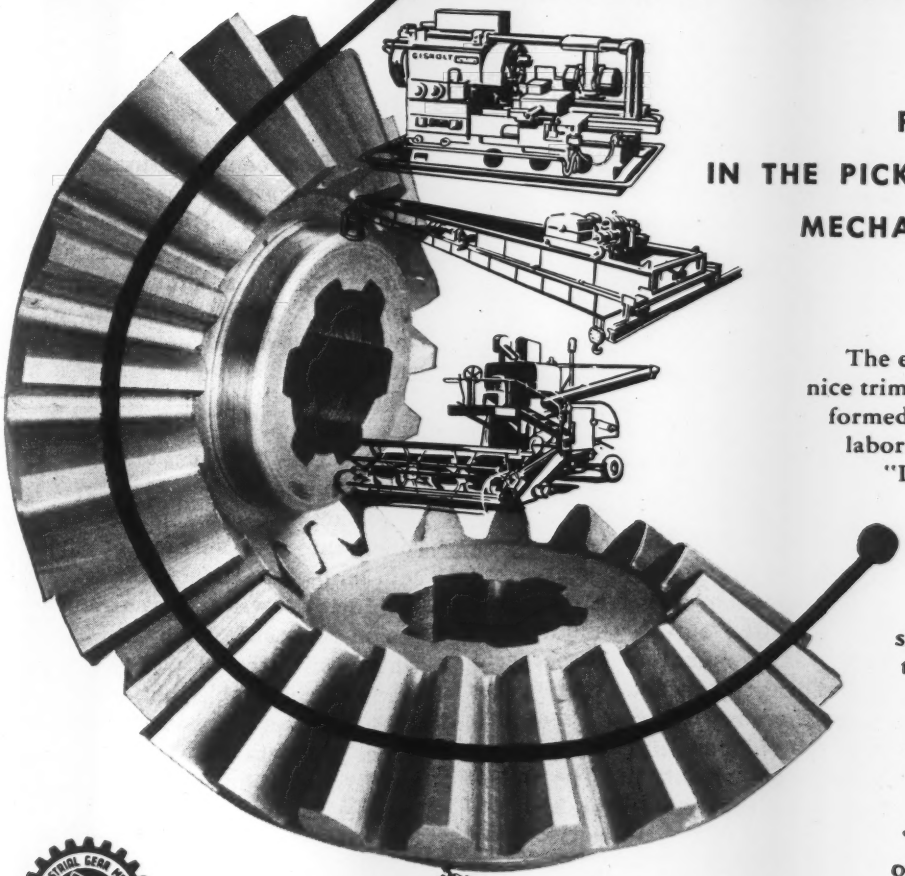
	COST PER PIECE		
	FORGING MATERIAL	HEAT TREATMENT	TOTAL COST MATERIAL AND HEAT TREATMENT
8620 CARB. AND DIRECT QUENCHED	$1.123	$0.095	$1.218
1022 CARB. AND INDUCTION HARDENED	.936	*0.182	1.118
1050 INDUCTION HARDENED	.929	0.094	1.023

* INCLUDES REBROACHING OPERATION

Fig. 6 — Camparative cost data for three medium-size gears, $4\frac{3}{4}$-inch OD, 26 teeth



Industrial Cut Gears



PLAY AN IMPORTANT ROLE IN THE PICKUP, FEED AND WIRE-TYING MECHANISMS OF JOHN DEERE AUTOMATIC HAY BALERS

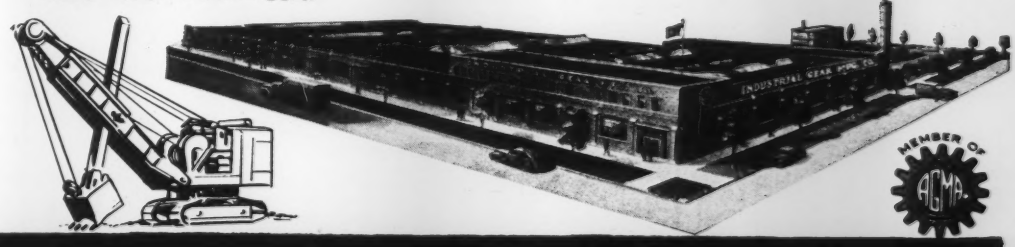
The end result of John Deere Hay Balers is a nice trim, leafier and more nutritious bale of hay formed speedily and compactly with minimum labor and power. Among its components are "Industrial Cut Bevel Gears" which make this essential implement of farming function smoothly and efficiently.

"Industrial Cut Gears" are important adjuncts in hundreds of mobile and stationary pieces of equipment. They are tailored to fit each application perfectly, hence assure long, dependable service with minimum maintenance cost. "Industrial Cut Gears" will prove to be the economical answer to your drive problems too! It will pay you to write "IG-Durocase" (Steel Mill Type Gears) or "IG-General Service Gears" into your specifications. They'll fulfill your every expectation.

INDUSTRIAL GEAR MFG. CO. IG GEARS SERVE INDUSTRY

INDUSTRIAL GEAR MFG. CO. CHICAGO IG DUROCASE GEARS SERVE THE STEEL INDUSTRY

Our modern plant grew to large proportions because of the service we render . . . and because gear and sprocket cutting is our bread and butter—not a sideline. Write for Bulletin No. 152-A and see how well equipped we are to handle your needs.



MEMBER OF AGMA

Industrial Gear Mfg. Co.

4529 W. VAN BUREN ST.
CHICAGO 24, ILLINOIS

Why SEARCH for ANSWERS?

When oil-hydraulics is involved-

-call in your DENISON FIELD ENGINEER

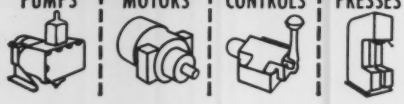
What he doesn't already know about hydraulics, he can get from Denison's full staff of design engineers. They're specialists, too. And all these men—in the field and in the plant—are experts in helping industry find new ways to trim costs . . . simplify hydraulic systems . . . combine two or more production steps into one quick operation or sequence . . . or even attain *automation* that goes all-out to shrink scrap losses, slash labor costs, and inspection needs, stretch tool and die life, and rout other profit-stealers you may now have to combat.

Wherever you think or *hope* oil hydraulics might do a better job of meeting your needs for controlled **power, motion, or pressure,** call in your Denison field engineer. He's keenly interested in *helping* you without *obligating* you.

**Denison makes the famous Multipress in one-ton to 75-ton capacities. Also pumps, fluid motors, controls, and valves for all high-pressure circuit needs within the 5000 psi range.*

DENISON HydrOILics

PUMPS | MOTORS | CONTROLS | PRESSES



The DENISON Engineering Co.
1156 Dublin Road, Columbus 16, Ohio

Design Abstracts

if accurate determinations of tooth action are desired, or a torsion shaft with a vernier mounted on parallel discs if average torque values are desired. The torsion shaft and vernier design has some merit in that it is trouble free and the indicated torque does not change between static and dynamic conditions.

Service life of gears in tractors on transmission dynamometers and on field tests compared to results of tests in the four-square, gear-fatigue test machine indicate that the results from the four-square machine are an accurate basis for predicting field service.

Summary of Results: The following discussion summarizes the conclusions we have drawn from an evaluation of the results obtained through laboratory gear tests and field experience.

Induction-hardened 1050 steel with a 500 F temper produces a strong, impact-resistant gear for slow-speed operation. This process also provides a substantial cost reduction over 8620 carburized and direct quenched. Beam strength tests in the laboratory are a practical, accurate measure of field service on this type of gear.

Induction hardening a ring gear decreases the out-of-roundness error by approximately 40 per cent over direct-quenched ring gears and thereby reduces assembly stress by 55 per cent, for the same amounts of shrink fit. The induction hardening provided 100 per cent improvement in service life as compared to direct quenching.

For gears subject to many millions of revolutions at relatively high loads we have found that carburized, air cooled, induction hardened and rebroached gears have the following advantages:

1. Straight spline bore.
2. Better resistance to wear.
3. Better resistance to pitting and fatigue.
4. The process can be used on a variety of steels; carbon steel to reduce cost and substitute steels in cases of emergency.

Laboratory fatigue test results in the four-square machine can be correlated to field service. Beam strength tests do not provide a measure of the service life of speed-change gears. Fatigue life of speed-change gears is not directly related to core hardness; that is, low core hardness may give good wear and fatigue life.

From a paper entitled "Engineering Evaluation of Gear Manufacturing Processes" presented at the SAE Annual Meeting in Detroit, Mich., January, 1954.

Surface Finishes for Magnesium

By Hugo A. Barbian

Technical Service and Development
Magnesium Dept.
Dow Chemical Co.
Midland, Mich.

THE first consideration for finishing material is to obtain a surface free from contamination. This is necessary for best finishing results and for maximum corrosion resistance. Magnesium may have several types of contamination which must be eliminated. An alkaline cleaner of the heavy duty type designed for steel with pH above 11 is very satisfactory for magnesium.

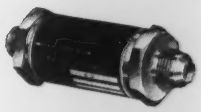
For mill scale or heavy metals rolled into the surface of sheets, contamination should be removed with acid pickles for maximum corrosion resistance. Any acid pickle which will remove 0.0005-inch of metal is acceptable, but the acetic-nitrate pickle has been found best. Sheet products are available in this pickled condition. Sand blasting of magnesium castings increases the corrosion rate markedly, so blasting should be followed by an acid pickle. Any acid pickle which will remove 0.0002-inch of metal will serve to remove the effects of blasting—8 per cent nitric-2 per cent sulfuric or 2 to 3 per cent sulfuric acids are most commonly employed.

Coating Requirements: Magnesium surfaces, like zinc surfaces, are naturally alkaline. To retard the formation of free alkali at the surface of the metal, a chromate-containing treatment should be selected. Certain primers which are compatible with alkaline surfaces can be used on bare magnesium with good adhesion. These primers con-

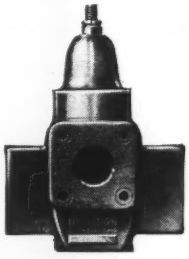
For lasting efficiency with less maintenance, specify

DENISON HydrOILic PUMPS, MOTORS, CONTROLS

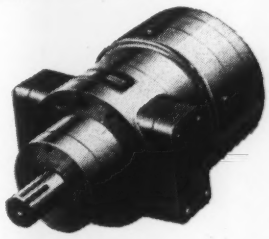
For circuit pressures to 5000 psi



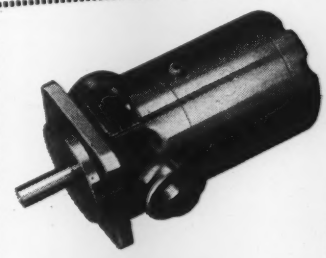
SURGE-DAMPING CONTROLS
Industrial and Aircraft Types
Eliminate Destructive Hydraulic Pressure Shock
¼" to 1" Sizes
For Pressures to 5000 psi
Catalog VS-1-A



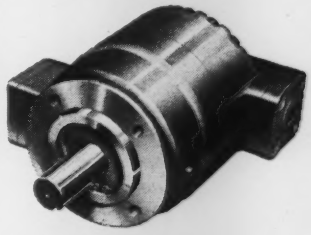
Direct-Operating PRESSURE CONTROLS
½" to 1½" Sizes
For Pressures to 2000 psi
Catalogs VRD-1 through VRD-8



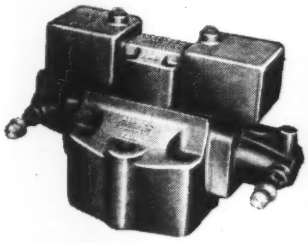
High-Pressure Axial-Piston PUMPS
Constant or Variable Volume
For 2500, 3000 and 5000 psi Circuit Needs
3.5 to 35 gpm Capacities
Catalogs P-4 through P-4-10



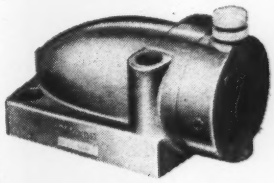
High-Torque Axial Piston FLUID MOTORS
Torque Ratings 13.8 to 112 inch-pounds per 100 psi (about 3 to 180 hp maximum)
For Pressures to 5000 psi
1500 to 3000 rpm
Catalogs FM-1, FM-2, FM-3-A



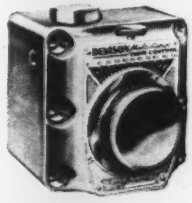
Dual-Purpose, Vane-Type PUMP/MOTOR
Ready for either pump or motor use without change
Shaft rotation in either direction
Four Sizes, 11 Models
Pumping Capacities: 3 to 82 gpm.
Motor Torque: 13 to 257 inch-pounds per 100 psi. Pressures to 2000 psi.
Bulletin P-5



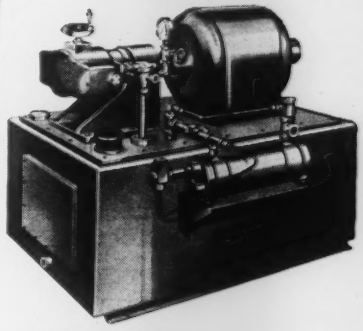
DIRECTIONAL CONTROLS
Manual, Mechanical, Electric or Pilot Control. ¼" to 2" Sizes
For Pressures to 5000 psi
Catalog VD-3



PRESSURE REDUCING VALVES
¾" to 1½" Sizes
20 gpm to 65 gpm Capacities
For Pressures to 5000 psi
Catalog VPR-1



Multi-Range FLOW CONTROLS
Full-Scale Regulation—Adjustable for Varying Input
¼" to ¾" Sizes
For Pressures to 3000 psi
Catalogs VFC-1, VFC-2



PUMPING UNITS
Constant and Variable Volume
46 Models—2 to 35 gpm Capacities
For Pressures to 5000 psi
Bulletins PU-3-A, PU-4 and PU-5

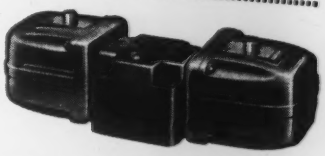
PROVED IN USE

under industry's toughest operating conditions

Denison HydrOILic Pumps, Motors and Controls are noted for their combination of high efficiency and rugged dependability.

In addition to fine performance under continuous, heavy-duty use, Denison HydrOILic Equipment offers space-saving design that simplifies circuit layout, makes installation easier, and minimizes maintenance problems.

Because so many users verify the extra value built into Denison Pumps, Motors and Controls, we continue the challenge made so often before—*let comparison prove to you* why they are first choice for so many needs of every type. Write today for full details on Denison HydrOILic Equipment to meet your requirements.



Pilot-Operated, Solenoid-Controlled DIRECTIONAL VALVES
Eliminate Spool-Sticking
¾" to 1½" Sizes, For Pressures to 5000 psi
Catalogs VD-1-1 to VD-4-2

Be sure to see DENISON BOOTH #1400 at ASTE SHOW

"The Finest Money Can Buy!"

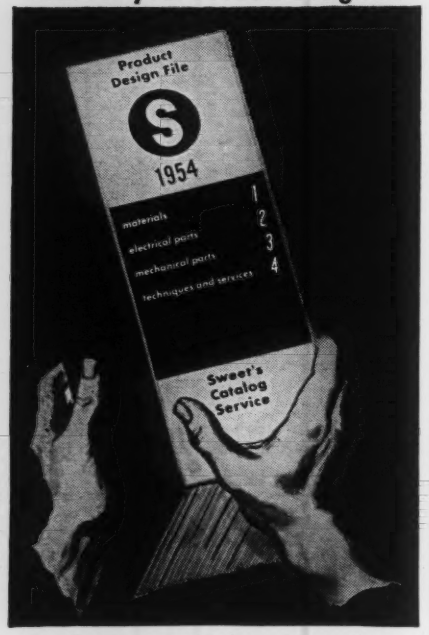
DENISON HydrOILics

PUMPS | MOTORS | CONTROLS | PRESSES

The DENISON Engineering Company, 1156 Dublin Road, Columbus 16, Ohio

need information on
electrical parts?

reach for your Product Design File



"...a great time-saver"

These manufacturers' catalogs are instantly available in Section 2 of your Product Design File:

A-P Controls Co.
Allen-Bradley Co.
Allis-Chalmers Co.
American Phenolic Corp.
Barber-Colman Co.
Barksdale Valves
Cannon Electric Co.
Century Electric Co.
Eagle Signal Corp.
Electric Specialty Co.
Electro-Snap Switch & Mfg. Co.
Elliott Company (Crocker-Wheeler Div.)
Emerson Electric Mfg. Co.
Fairchild Industries, Division Fairchild Camera & Instr. Corp.
Federal Telephone & Radio Co.
General Electric Co. Apparatus Mktg. Div. Const. Materials Div. Lamp Division Wiring Devices Dept.
General Radio Co.
Heinze Electric Co.
Howell Electric Motors Co.
Jefferson Electric Co.
Joy Mfg. Co.
Kato Engineering Co.
Master Appliance Mfg. Co.
Master Electric Co.
Mercoid Corp.
Mutual Industries
National Electrical Mfrs. Assn.
Ohmite Mfg. Co.
Radio Receptor Co.
Redmond Co., Inc.
Telechron Dept., General Electric Co.
Trombetta Solenoid Corp.
Wagner Electric Corp.
Ward Leonard Electric Co.
Westinghouse Air Brake Co.
Westinghouse Electric Corp.

In other sections of the File you will find additional catalogs containing useful information on product forms, characteristics, performance and use.

Sweet's Catalog Service

Division of
F. W. Dodge Corporation
119 West 40th Street,
New York 18, N. Y.

Design Abstracts

tain vinyl, epichlorhydrinbisphenol, or polyvinyl butyral resins.

Another basic consideration concerns the use of a chemical treatment for paint adhesion. This is a common practice for all metals. Paint adhesion can be obtained mechanically on magnesium with a selective etching treatment which makes a "tooth" into which the paint is locked. Paint adhesion can also be obtained by absorption. Anodic treatments for magnesium produce coatings which will absorb paints, oils, greases, and other such materials very readily.

A significant phase of magnesium finishing calls for good design and protection of dissimilar metal joints. This becomes especially important where equipment is used in salt-containing environments like sea coast sites or on the underside of automobiles and trucks. In these cases, improper design can lead to galvanic corrosion.

Galvanic Corrosion: Proper design to eliminate undesirable galvanic corrosion calls for certain steps. First the cathode (dissimilar metal) must be protected as well as the magnesium by the use of moisture impervious films such as vinyls. Where corrosion is a real problem, application of essentially nonporous coatings on magnesium (chemical treatment or paint) should be avoided unless they are applied to the dissimilar metal as well. It has been a common failing in field work to put more and more protection on the magnesium because it appears as though the magnesium is the member which is corroding and needs protection.

Another factor in proper design which tends to reduce the incidence of galvanic corrosion is the use of dissimilar metals which are compatible with magnesium. These metals include aluminum (52S, 53S, 56S, 61S and 63S), steel, brass, etc., with zinc or cadmium plate. The plate retards galvanic corrosion but does not prevent it. These metals can be utilized in washers, shims, fasteners and structural members.

Another means of reducing galvanic corrosion is by use of electroplated magnesium. A copper-nickel-chromium system eliminates the potential difference between the magnesium and the dissimilar metal and thus eliminates galvanic corrosion. This method is especially applicable to small parts.

From a paper entitled "Finishing Systems for Magnesium" presented at the Ninth Annual Meeting of the Magnesium Association in New York, N. Y., November, 1953.

Characteristics of Magnetic Amplifiers

By R. W. Moore

Manager
Control Development Engineering
Westinghouse Electric Corp.
Buffalo, N. Y.

APPLICATIONS of magnetic amplifiers have increased rapidly in the past five years. The magnetic amplifier neither replaces or supersedes the rotating or electronic amplifier but, because of a number of particular advantages, it fills a gap between these other two amplifier types and often is employed at present where one or a combination of both were previously used. Also, the magnetic amplifier can be combined readily with either the rotating or electronic amplifier. Such combinations have particular advantages for specific applications.

Magnetic Amplifier Operation: The magnetic amplifier can be described as a variable reactance between a source of ac voltage and a load. A small amount of control power can vary this reactance by

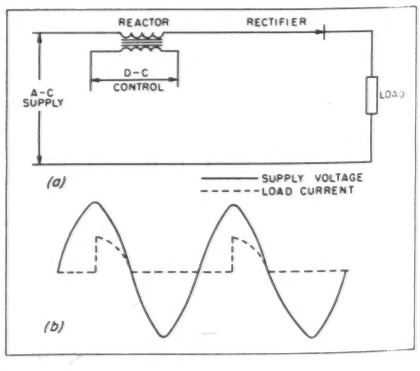


Fig. 1—Elementary self-saturating magnetic-amplifier circuit, *a*, and a typical output current waveshape, *b*

saturating a magnetic core which in turn controls large amounts of power to a load. Although this method of obtaining amplification has been known for many years, several recent developments have made possible the modern magnetic amplifier. First was the development of the self-saturating circuit which raised the ratio of power gain to response time by a factor of 100. Second was the development of magnetic materials which give high gain with high output. Third was the development of selenium and other dry-type rectifiers which function to improve gain, stability and reliability.

An elementary self-saturating magnetic amplifier, *Fig. 1a,* consists of a two-winding, iron-core reactor and a self-saturating rectifier. The ac or load winding and the rectifier are connected in series with an ac power supply and a load. Assume a dc signal is applied to the control winding. If the dc control current saturates the core in the same direction as the alternating supply voltage, minimum reactance and maximum load current is obtained. If the dc control current saturates the core in the opposite direction, maximum reactance and minimum load current is obtained. Output current waveshape for a typical control current value is shown in *Fig. 1b.*

However, this elementary circuit is not practical for two reasons. First, a transformer voltage is induced in the control winding which results in a large alternating current unless control-circuit

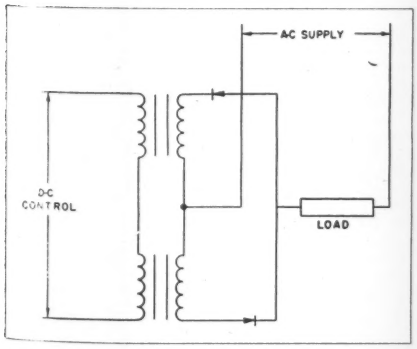
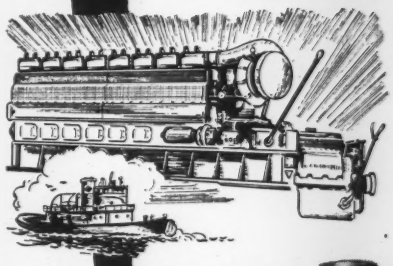


Fig. 2 — Practical self-saturating magnetic - amplifier circuit for ac load current control

For DEPENDABILITY

ERIE the correct fastener for the job!



Erie Fasteners are in wide use by the nation's leading Diesel Engine builders.

You can rely on over 40 years of experience in producing bolts, studs and nuts designed to withstand the effects of high and low temperatures, high stresses, fatigue and corrosion. Modern facilities enable our skilled craftsmen to produce to your specifications bolts, studs and nuts, precision machined and heat treated in carbon, alloy, stainless steel and nonferrous metals.

These Erie Products prove their quality every day in the railroad, chemical, petroleum and automotive industries; on farm, construction and industrial equipment and heavy machinery. Send your design and material specifications to us . . . we will make for you the Correct Fastener for the Job.

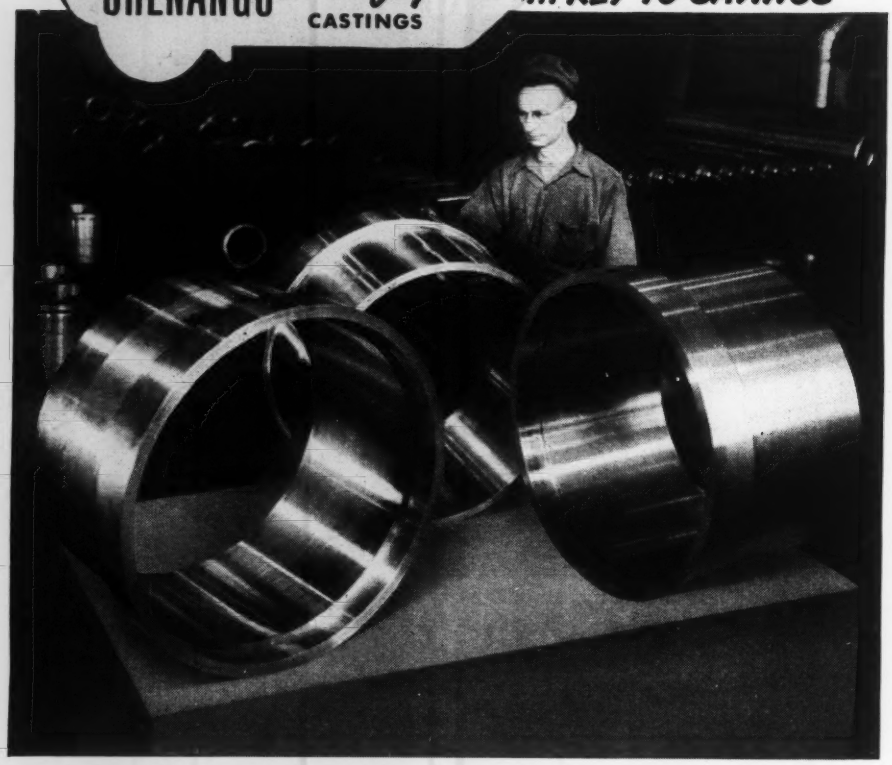
A SUBSIDIARY OF Barium STEEL CORPORATION

ERIE BOLT and NUT CO.
ERIE • PENNSYLVANIA

STUDS • BOLTS • NUTS
ALLOYS • STAINLESS
CARBON • BRONZE

Representatives in Principal Cities.

SHENANGO Centrifugal CASTINGS ... KEY TO SAVINGS



Basket centrifuge cylinders centrifugally cast in Monel Metal by Shenango. Used in superdehydrators for separating crystals given off from vacuum crystallizers.

3 REASONS WHY

SHENANGO parts give longer, more dependable Service

1 The special centrifugal casting process used by Shenango guarantees higher strength, pressure-dense castings free from sand inclusions, blowholes and other often hidden defects.

2 You specify the job and Shenango will supply the part cast in the exact metal formula for maximum service under your specific conditions.

3 Precision machining is done by skilled craftsmen in Shenango's modern machine shop. A good way to guarantee a perfect fit at minimum cost.

Send for Bulletin No. 150 covering nonferrous metal parts; Bulletin No. 151 covering Meehanite Metal, Ni-Resist and special iron alloys. *Address . . .*

SHENANGO-PENN MOLD COMPANY
Centrifugal Castings Division
Dover, Ohio
Executive Offices: Pittsburgh, Pa.

SHENANGO
ALL RED BRONZES • MANGANESE BRONZES • ALUMINUM BRONZES
MONEL METAL • NI-RESIST • MEEHANITE® METAL

impedance is high. Second, load current is obtained only every other half cycle.

A practical circuit design is illustrated in *Fig.* 2. The impedance of the control winding is determined only by the dc control voltage because the induced ac voltages in the control winding cancel. Also load current can be obtained every half cycle.

More commonly, dc output is required from magnetic amplifier regulators for industrial applications. *Fig.* 3*a* illustrates the parallel self-saturating circuit with a bridge rectifier to dc load current, and *Fig.* 3*b* illustrates a circuit using reactors and a bridge rectifier to obtain self-saturation and dc output. These basic circuits illustrate magnetic amplifiers for use with single-phase supplies. Such circuits can also be used with three-phase power supplies and the extension can be made readily by the addition of the required reactors and rectifiers.

Control Characteristics: The control characteristics of a magnetic amplifier built with a wound gapless, nickel-alloy core are shown in *Fig.* 4. The core hysteresis characteristic of this toroidal type reactor is rectangular in shape. Thus, the control characteristic has a wide linear range and a small amount of dc control ampere-turns controls the output from minimum to maximum. The minimum output current or cut-off current is

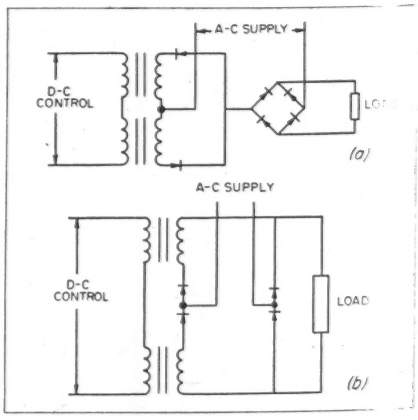
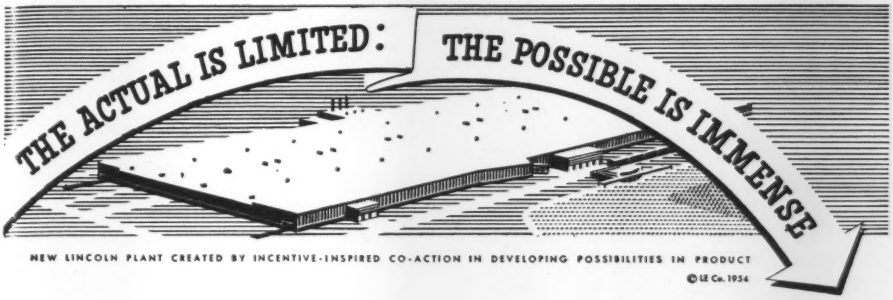


Fig. 3—Two basic types of bridge circuits for obtaining controlled dc output



Good Engineering Designs depend on low cost

SAVES MATERIAL, SIMPLIFIES MANUFACTURE, WITH WELDED STEEL

. . . to cut production costs

TODAY'S demand is for stronger, yet lighter machinery that can handle lighter loads, be more durable in service and have modern appearance.

To meet such demands, this fabricator was authorized to analyze the potentials of welded steel construction on one of his machines.

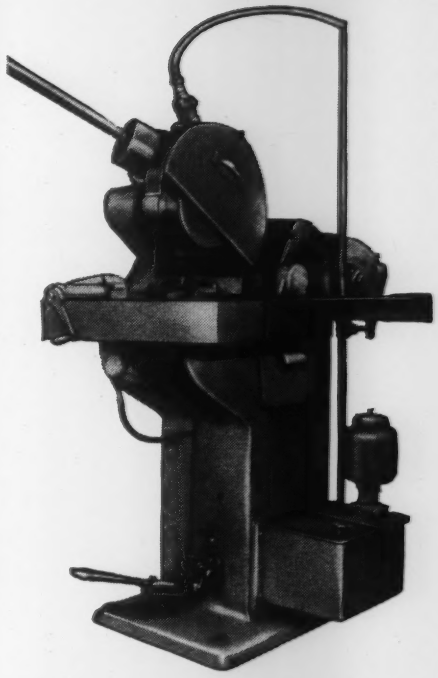
Resulting improvements in ruggedness made at considerable savings in cost prompted further analysis of other equipment. Ultimately, the rest of this customer's line of machinery was converted to welded steel construction.

By the proper use of steel, this fabricator has been able to realize substantial reductions in weight and cost.

In the first redesign, the steel machine base follows the basic outline of the original castings. However, only 764 pounds of low cost welded steel plate are needed to replace 1048 pounds of gray iron . . . an initial material saving of 28%. Machining has been eliminated. There are no bolted joints to cause coolant leakage.

The present design requires even less metal. Eight hours less fabricating is required . . . cutting shop costs still further.

Machining operations formerly needed to remove 50 pounds of cast iron have been eliminated entirely . . . as well as the costly manhours to fill and paint castings.



Original Construction Wet cut-off abrasive machine was formerly made from castings . . . had member components of base bolted together. Each casting required machining and fitting in assembly thus building up cost.

Photos courtesy of Boiler Repair & Welding Co., 101 Islandbrook Avenue, Bridgeport, Connecticut

First redesign of machine base duplicates outline of original cast construction . . . yet cuts material need from 1048 lbs. to 764 lbs. Requires only 31 hours to fabricate.

Present design provides compact, sturdy box construction occupying less floor area. Needs fewer components . . . requires 26% fewer manhours to fabricate.

HOW TO BENEFIT FROM WELDED STEEL

Lincoln Bulletins on Welded design are available to designers and production engineers, or your Lincoln representative will gladly assist in planning for lower cost construction.

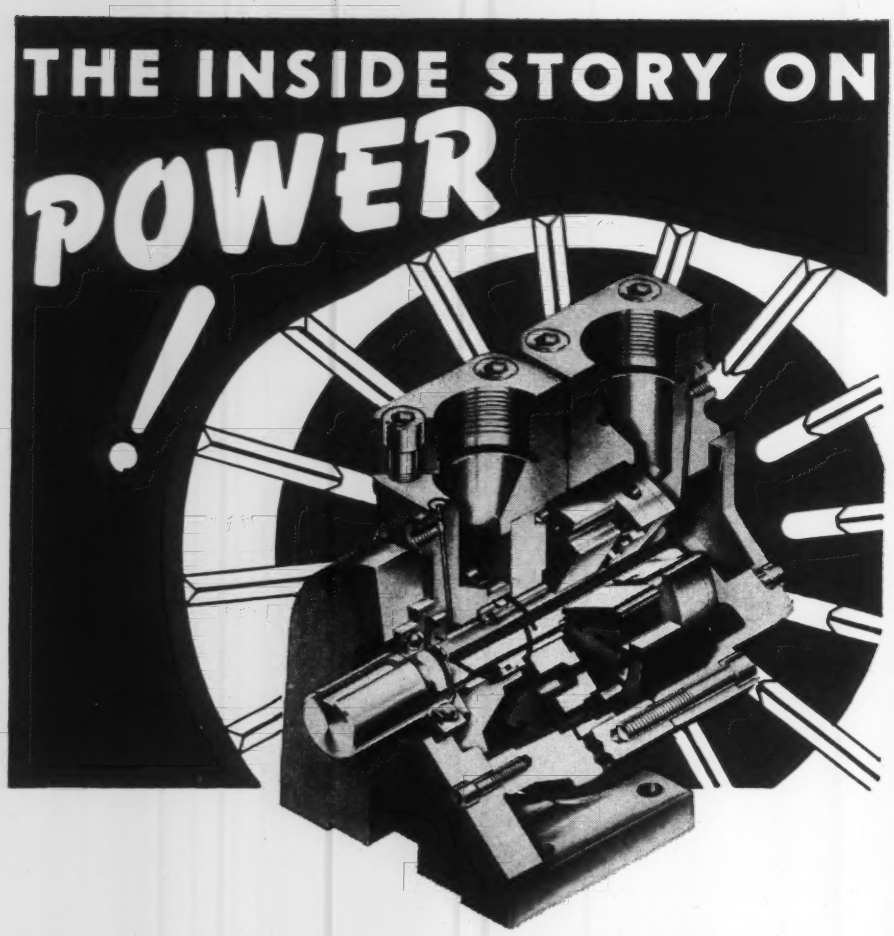
LINCOLN'S LEADERSHIP in arc welding is founded on one idea . . . to produce a better product at lowest cost through incentive operation.

THE LINCOLN ELECTRIC COMPANY

Dept. 1103

CLEVELAND 17, OHIO

THE WORLD'S LARGEST MANUFACTURER OF ARC WELDING EQUIPMENT

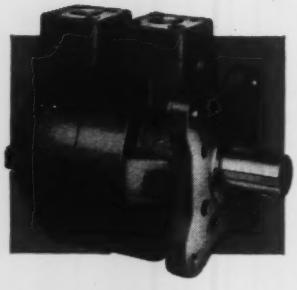


the ALL Way Balanced Dual-Vane

DUDCO

HYDRAULIC PUMP

One look at the inside of a DUDCO Pump tells the story of efficiency through *fully* balanced construction. Note how, at all times, the Dual-Vanes provide a *double* barrier to slippage and lost power. These DUDCO Vanes are individually balanced to closely follow the cam ring contour without wear-producing thrust . . . their unique displacement action provides an extra 15% to 20% added volume.



Featuring starting torques higher than running torques, DUDCO has long been recognized as the most efficient Fluid Motor in the field. Standard models from 180 lb. in. to 14,400 lb. in.

Smooth, non-pulsating DUDCO power, delivering 2000 psi for continuous operation, frequently doubles the capacity of less efficient hydraulic circuits. Standard models from 3 gpm to 120 gpm.

DUDCO DIVISION
THE NEW YORK AIR BRAKE COMPANY
1706 EAST NINE MILE ROAD • HAZEL PARK • MICH.

Design Abstracts

low because of the gapless construction. Amplifiers of this type are built with outputs ranging from a few milliwatts to a 1000 watts. Such amplifiers are sensitive to changes of a few microwatts in power input and require only a small milliwatt change in input power to obtain a change from minimum to maximum power output.

The control characteristic of a self-saturating magnetic amplifier having a wound core of grain-oriented silicon steel which is cut and reassembled with butt joints is shown in *Fig.* 5. Magnetic amplifiers made in this manner have higher minimum output currents than those having gapless cores and not as high a gain. Amplifiers of this type are used as power amplifiers or in systems where extremely high-power gain is not required, although positive feed back or series self-energization can be used to increase gain materially.

The control characteristics illustrate an inherent property of single-channel dc magnetic amplifiers. That is, the output is unidirectional and the minimum output is finite value. A variety of circuits have been developed such that dc output in both directions can be obtained. As illustrated in *Fig.* 6*a*, two magnetic amplifiers can be connected by a resistor network in a "push-pull" arrangement to give a net positive or negative output. This arrangement is often used as an interstage connection in multistage two-channel amplifiers.

If magnetic amplifiers are used

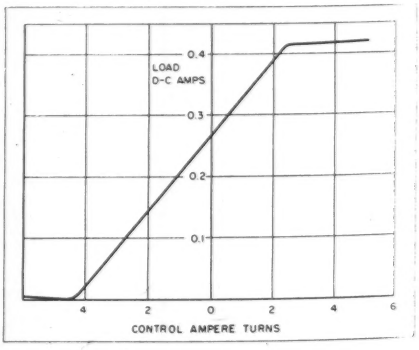


Fig. 4 — Control characteristic of high-gain type magnetic amplifier with nickel-alloy core

to excite a generator, for example, two amplifiers can be employed with each exciting a separate field on the generator, *Fig.* 6*b*. If this generator supplies variable voltage to the main drive of a nonreversing mill, the reverse field can be used to obtain reverse forcing, precise stops, and low-speed reverse inching.

It is economically feasible to use all magnetic-amplifier control on some reversing drives. A bridge-type connection as illustrated in *Fig.* 6*c* can be used for reversing control.

Control characteristics of an individual magnetic amplifier which makes up a reversing amplifier can be combined to form a control characteristic such as illustrated in *Fig.* 7. Since operating ranges of individual amplifiers are readily adjustable, a control characteristic suitable for a limit-type regulator can be obtained, *Fig.* 8. This control characteristic has a dead zone at zero output for a range of control signal values, but outside the dead zone high-gain amplification is obtained. The control characteristic illustrated can be used to obtain both current-limit acceleration and deceleration. If the controlled quantity need be limited in only one direction, only a single-channel amplifier is necessary.

Application Considerations: A time constant can be defined for a magnetic amplifier just as for any electromagnetic device, except that with the circuits previously illus-

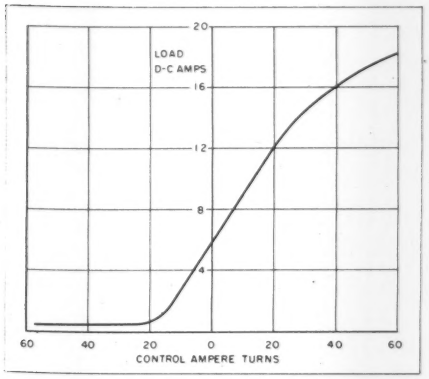
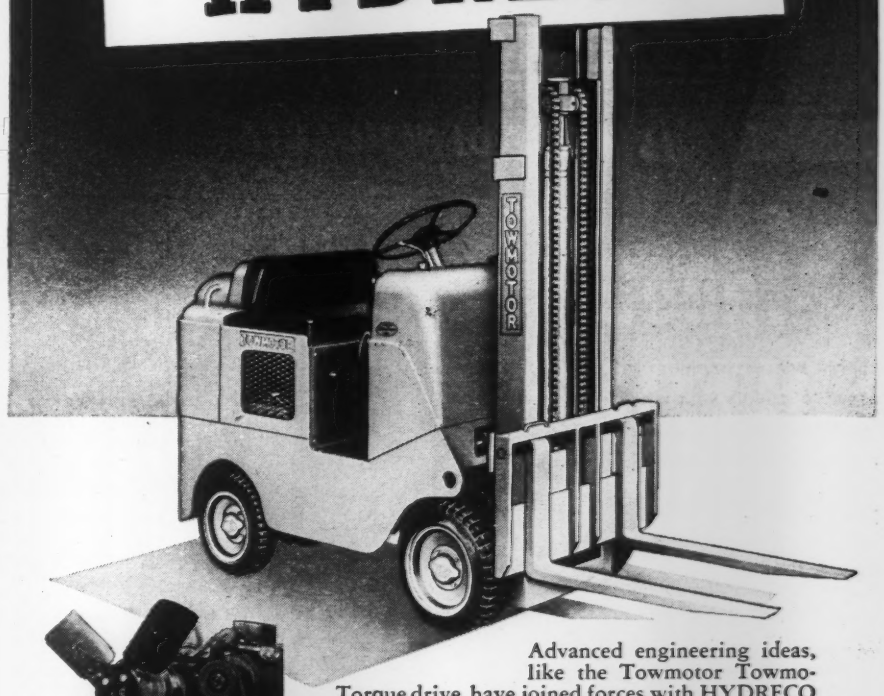
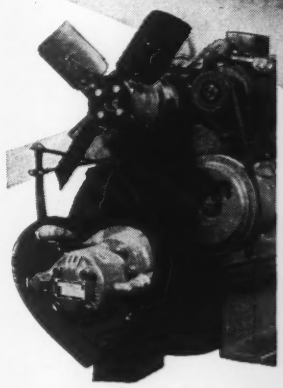


Fig. 5 — Control characteristic of high-power type magnetic amplifier with silicon-steel core

It's No Coincidence That TowmoTorque Control is Oil Powered by HYDRECO



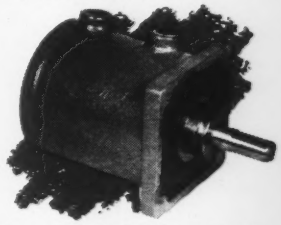


The famous HYDRECO Four-Bolt design gear-type Pump for 1000 to 1500 psi applications is the heart of the Towmotor hoist circuit.

Advanced engineering ideas, like the Towmotor TowmoTorque drive, have joined forces with HYDRECO Oil Power too consistently to be a coincidence.

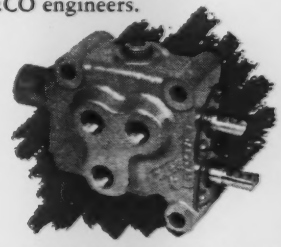
Of interest to design engineers is the hydraulics problem successfully solved here. The control of the torque converter drive through a specially-designed HYDRECO valve enables the operator to control vehicle speed independently of the hoisting speed. For example, the operator can drive the truck forward and backward very slowly while raising the load at maximum speed. Other HYDRECO components on this truck include a special cylinder and relief valve for the TowmoTorque, and a pump, control valve and cylinder for the hoist circuit.

HYDRECO Oil Power is providing a definite sales advantage to more and more makes and models of mobile equipment, machine tools and special machinery. And, frequently you'll find that the things you're dreaming up are problems already solved by HYDRECO engineers.



A compact HYDRECO cylinder designed with low-friction characteristics actuates the TowmoTorque drive.

This HYDRECO relief valve is used on the torque converter to protect the heat exchanger from excess pressure.



Located beneath the floorboards is the HYDRECO-designed valve, one plunger of which is connected to a hand lever and hydraulically controls the forward and reverse motion of the truck. The other plunger, connected to a foot pedal, controls the vehicle speed regardless of engine speed.

Write

Write for the latest HYDRECO bulletins on Pumps, Motors, Valves and Cylinders.

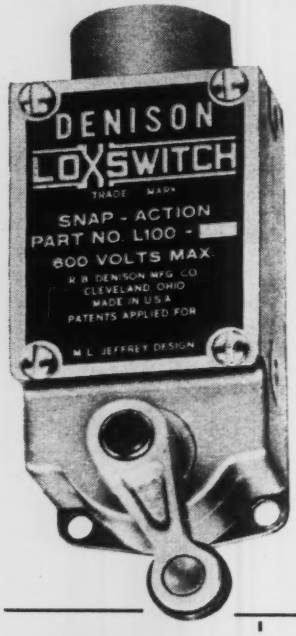
HYDRECO DIVISION
THE NEW YORK AIR BRAKE COMPANY
1106 EAST 222nd STREET • CLEVELAND 17 • OHIO

PROOF

LOXSWITCH HEAVY DUTY LIMIT SWITCH IS MORE DEPENDABLE

	Denison Loxswitch L-100	Switch B	Switch C
Speed of Break—Inches per Second**	48	25	24
Typical "Ounce"—Miliseconds**	4	16	9
Contact Bar Pressure—oz.*	10	4	7
Torque to actuate with return spring—In. Oz.*	170	220	230
Torque to produce overtravel—15°—In. Oz.*	185	435	360
Torque to actuate with return spring removed—In. Oz.*	45	75	65
Torque to produce reverse overtravel	40	435	360

*Tests by James H. Herron Company, testing laboratory
**Tests by F. E. Brammer, assoc. professor, Dept. of Electrical Engineering, Case Institute of Technology



These tests prove conclusively the superiority of Loxswitch Limit Switches. Note the faster break due to the trigger-type operating mechanism and the greater contact pressure. Also observe the lower torque required to operate a Loxswitch. This means less strain on the switch . . . and far longer life . . . over 25,000,000 actuations in mechanical tests. Why settle for less? Standardize today on Loxswitch limit switches, made to J.I.C. standards. Easily adapted to most existing installations. All parts are quickly replaced with standard tools. Prompt delivery. Wire, write or phone today.

MAIL COUPON

For Further Information

R. B. DENISON MFG. CO.

102 St. Clair Ave., N.W. • Cleveland 13, Ohio

Gentlemen:
Please send me your catalog and price list on Loxswitch limit switches:

Name _____ Title _____

Company _____

Address _____

City _____ State _____

LOXSWITCH

Design Abstracts

trated, the minimum time delay obtainable is approximately two cycles of the supply frequency. Also, the size of a reactor for a given power output is inversely proportional to the supply frequency. Therefore, the use of magnetic amplifiers on power supplies of less than 50 cycles is generally not economical, and satisfactory regulating system performance is difficult to obtain. Conversely, the use of higher frequencies gives improved system performance and smaller

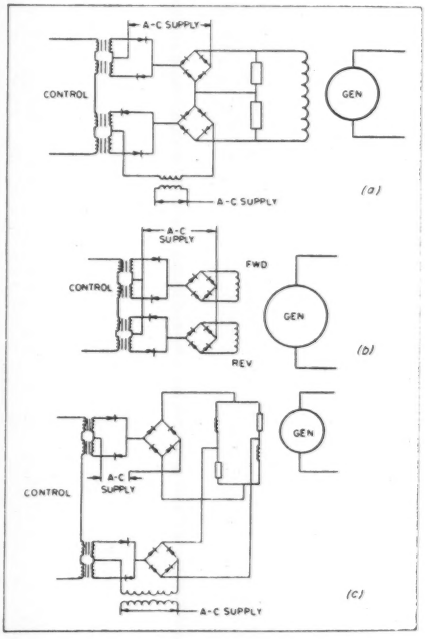


Fig. 6—Circuits for dc load current reversing with push-pull connection, *a*, two-channel connection, *b*, and bridge connection, *c*

size reactors. Power supplies and magnetic amplifiers for 400 cycles have been developed for military applications. Where the ultimate in performance is desired, these 400-cycle units can be applied for industrial drives.

Since the magnetic amplifier is used in series with an ac supply voltage and a load, any variations in the supply voltage or frequency affect the load current. Effects of these variations are reduced in a regulated system by the gain ahead of the magnetic amplifier. Since the frequency of most power systems is held closely, frequency variations generally are negligible. However, variations in supply volt-

Fast Movers or Shelf Warmers?

Count BOTH

(and 1,001 Other Items)

WITH

VARY-TALLY

Multiple-Unit Reset Counter

Vary-Tallies help you separate the sheep from the goats, the big ones from the little ones, the red ones from the green ones — in manufacturing, sales, accounting, researching and what not!

Vary-Tallies will do *any* counting job you want in any combination up to 6 banks high, 12 units wide (with a minimum of 12 units wide). Yes, you can count on 'em or with 'em *to your profit* — note these features of construction:

- **Easily Readable from Any Angle . . . Bold figures Always Centered in Window . . . No Glare . . . Figures not Covered by Fingers in Operation**
- **Easily Portable, yet Ruggedly Built for Long Wear**
- **All Parts Corrosion-Resistant; Working parts of Hardened Steel**
- **Separate Counting Units Can be Rotated like Tires on a Car, to Distribute Wear Evenly**
- **Not Affected by Extreme Heat or Cold**
- **Individual Tag Above Each Counter-Window — Not Strip Tabs**
- **Veeder-Root Quality in Every Part**

How Can the Vary-Tally count for *you*? Write for news sheet and prices.

"The Name that Counts"

VEEDER-ROOT INC.

HARTFORD 2, CONNECTICUT

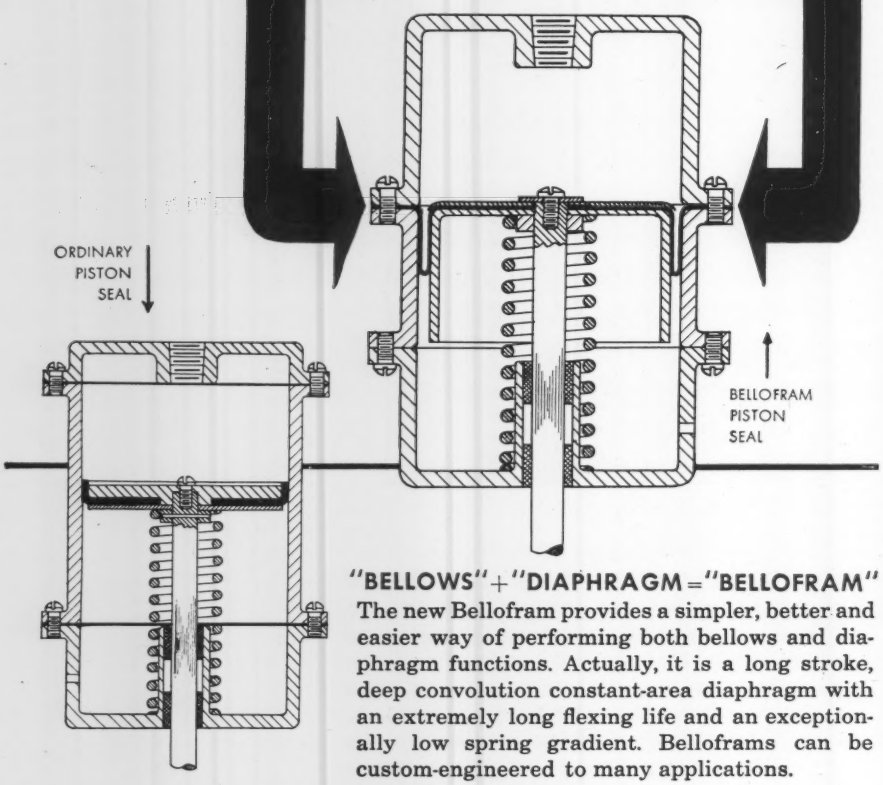
Chicago 6, Ill. • New York 19, N. Y. • Greenville, S. C. • Montreal 2, Canada • Dundee, Scotland • Offices and Agents in Principal Cities

NEW

Bellofram*

PISTON SEAL

for *frictionless* power



"BELLOWS" + "DIAPHRAGM = "BELLOFRAM"

The new Bellofram provides a simpler, better and easier way of performing both bellows and diaphragm functions. Actually, it is a long stroke, deep convolution constant-area diaphragm with an extremely long flexing life and an exceptionally low spring gradient. Belloframs can be custom-engineered to many applications.

BELLOFRAM PISTON SEALS

Belloframs are clean – eliminate gas or fluid leakage and need no lubrication – friction losses low, even under high pressure – relatively unaffected by foreign matter – friction-free rolling action gives exceptional cycle life – have high dielectric strength – remarkably resistant to all chemical action – area accuracies entirely dependent on surrounding rigid parts – adapts itself to chamber or cylinder irregularities. Bellofram Piston Seals do what no other piston seals can do with more accuracy, efficiency and economy.

NEW FREEDOM FOR DESIGNERS

Belloframs give exceptional cycle life. Infrequent and simple replacement is the only maintenance. They can be made to operate at pressures ranging from ¼" H_2O min. to 500 PSIG maximum over a wide range of temperatures. Effective area can be controlled to within less than 0.1% over the working stroke. Ask about a Bellofram designed to meet *your* specific needs. Send us a sketch of your device and we will show you how simply Bellofram may be applied. Strictest confidence observed. Write today.

© BELLOFRAM CORP. 1954

*Trade Mark

Bellofram
CORPORATION
144 MOODY ST., WALTHAM, MASS.

Design Abstracts

age may be as high as 10 per cent. Variations of this magnitude may require the addition of constant-voltage transformers between the supply and the magnetic amplifiers, or circuits must be used which compensate for these voltage variations.

Self-saturating magnetic amplifiers of the high-gain sensitive type are built with power outputs varying from 0.04 to 1000 watts. High-power self-saturating magnetic amplifiers of the less sensitive type are available in ratings from 100

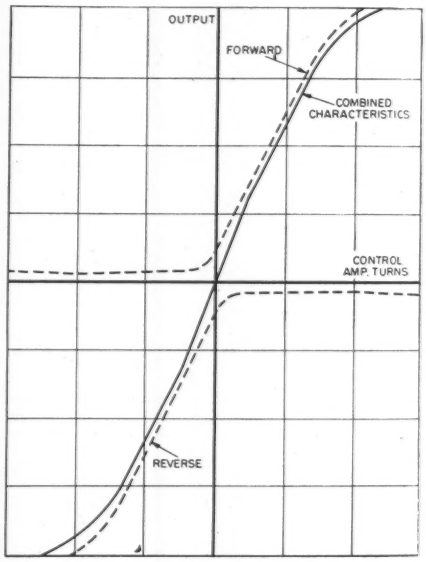


Fig. 7—Two-channel magnetic-amplifier control characteristic curves

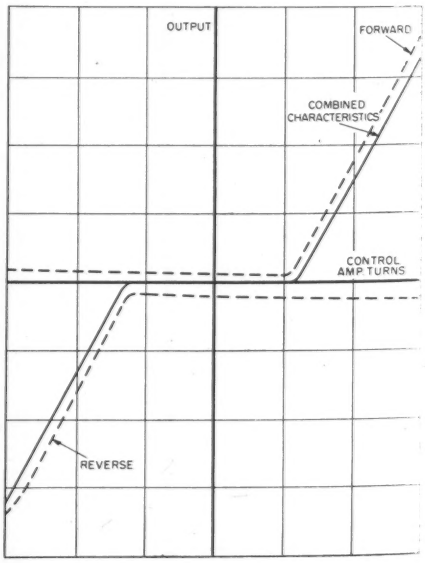
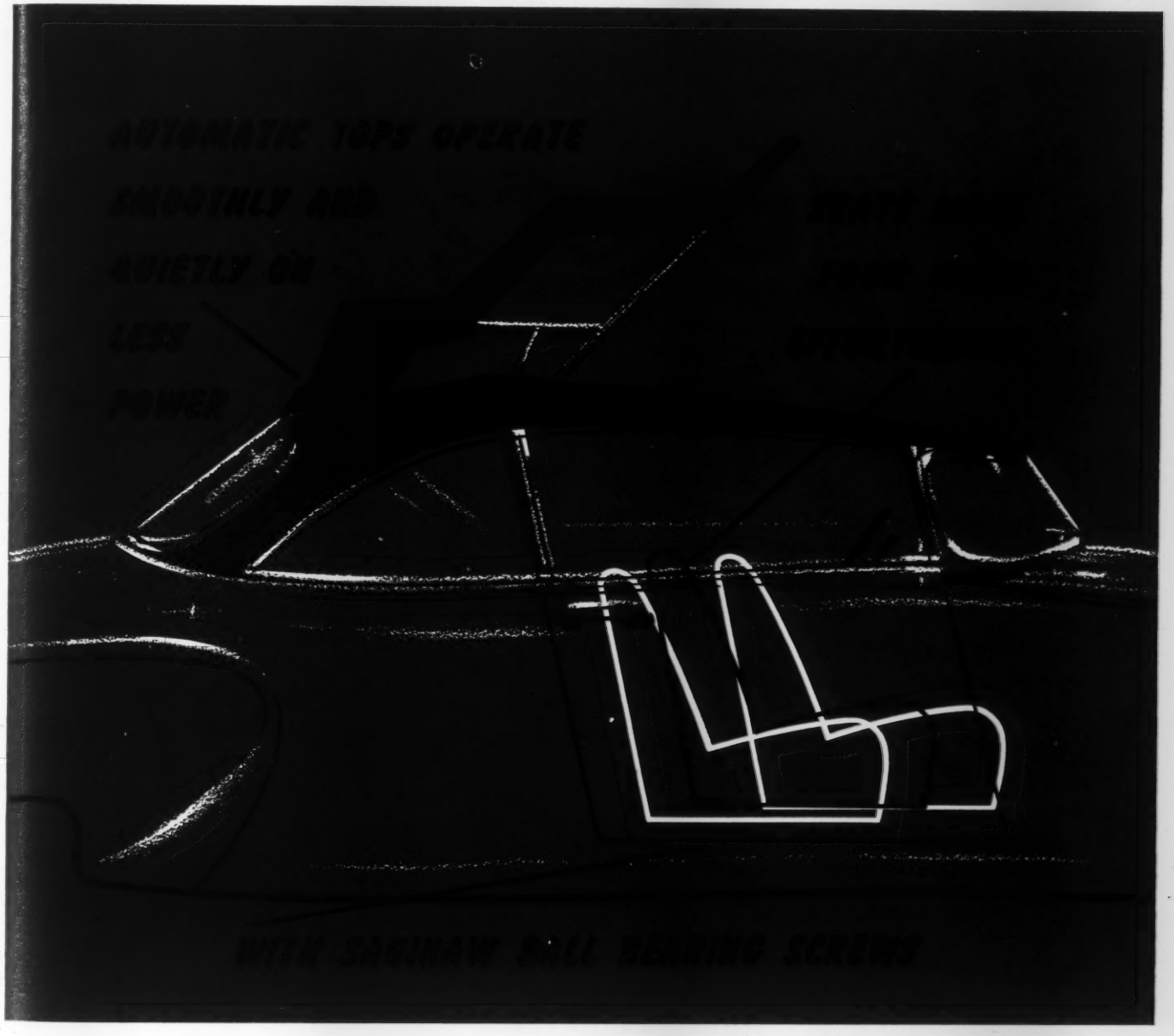
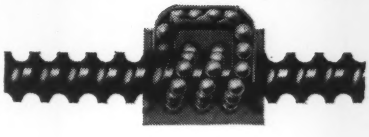


Fig. 8 — Control characteristic for limit type regulators





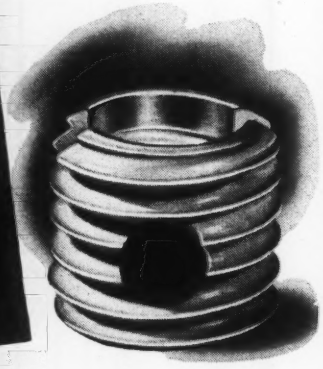
It takes very little battery power to operate the new four-way seat adjustment or to raise and lower the new quiet-operating automatic tops when Saginaw Ball Bearing Screws actuate the mechanism. These highly efficient screw assemblies transmit the rotary to linear force through rolling steel balls with less than 10% friction loss, thereby reducing the torque requirements to operate the mechanism. Saginaw Screws are also very effective in heavy duty applications like machine tools and in precision applications such as aircraft controls. Depending on the type of application, Saginaw Screws can cut power requirements as much as ⅓ and improve the performance of your product as well. Write today for our engineering data book giving you complete information.

Saginaw STEERING GEAR DIVISION

68

GENERAL MOTORS CORPORATION, SAGINAW, MICHIGAN • MANUFACTURERS OF SAFETY POWER STEERING

NYLOK'S Self-locking THREADED INSERTS...



• For use principally in non-ferrous forgings, castings and extrusions

CUT COSTS because NYLOK threaded inserts eliminate counterboring, special tapping and all the secondary operations required by other threaded inserts. With NYLOK inserts, simply drill and tap with standard tools — then screw the insert in place. They give stronger, tighter fastenings which will permit fewer fastenings per application.

PROTECT PARTS because they eliminate thread failure in expensive castings by absorbing stresses and prevent thread wear and stripping.

DOUBLE LOCK because with the resilient nylon plug, NYLOK inserts provide a smooth, positive locking torque on both internal and external threads, thus locking the insert in the casting and also securely locking the bolt once it has been threaded into the insert.

REQUIRE NO SPECIAL TOOLS for insertion or removal. Permits use of standard screw driver. Simplifies maintenance in the field.

How NYLOK THREADED INSERTS work . . .

Resilient nylon plug (A) sets up lateral thrust on both internal and external threads, smoothly wedging mating threads together, both on casting and bolt (B) and (C). There is no galling, no thread distortion, no mutilation of mating threads. All of locking action is on threads and locking is positive. The inserts may be used and reused many times without impairing the locking feature.

For complete details on how NYLOK threaded inserts may solve your fastening problems, write today. NYLOK engineers will gladly discuss them with you at no obligation.

THE NYLOK Corporation

Manufacturers of Nylon-Locked fasteners covered by U.S. patents and patents pending

Main Offices and Factory — Elmira Heights, N. Y.

Offices in: New York City • Detroit • Chicago • North Hollywood

Design Abstracts

watts to 45 kilowatts. Present practice seems to indicate that high-gain, self-saturating magnetic amplifiers are best applied where the total control power is not less than a few milliwatts and changes in control signal are not less than a few microwatts. High-power magnetic amplifiers are best applied where the power output required is 10 kilowatts or less.

Magnetic Amplifier Advantages: The unique combination of characteristics offered by magamps provides a number of specific application advantages:

1. Magnetic amplifiers are static devices. Long life and minimum maintenance associated with reactors and dry-type rectifiers can be expected. No periodic maintenance is necessary.

2. Reactors and rectifiers are highly resistant to shock.

3. No warm-up is necessary since the magnetic amplifier is immediately operative when power is turned on.

4. Control windings are electrically isolated, thus isolating control signals. In addition, this permits independent adjustments of control signal effects, and wide variations of input impedances for various signal sources. Magnetic amplifiers are therefore flexible in application.

5. Control windings are electrically isolated from power winding. Cascading of magnetic amplifiers to form multistage units is easily accomplished.

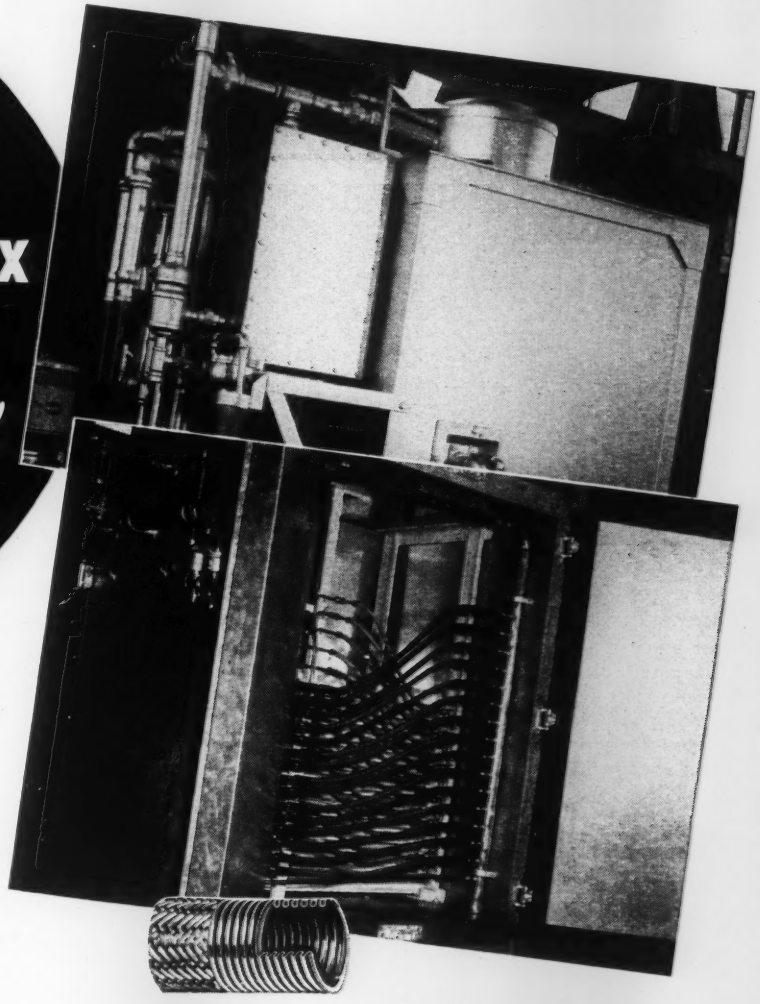
6. Magnetic amplifiers are panel mounted and factory wired; therefore they are easily installed. Panel mounting lends itself readily to packaging.

7. Circuit components used with magnetic amplifiers are relatively small. Control rheostats for high gain units can fit into pushbutton stations and devices for system damping can fit readily on magnetic-amplifier panels.

8. Higher frequency supply voltages can be used, thus regulating system design is simplified and improved performance obtained.

9. Magnetic amplifiers are flexible. A few ratings in a line of high gain toroidal reactors and

NOW
INDUSTRIAL REX-FLEX
Heavy Wall
Stainless Steel
HOSE



Available in four types to meet every design need

TYPE RF-44—Annularly corrugated; sizes from 2½" through 6" I.D. for working pressures to 40 psi.

TYPE RF-45—Same as Type RF-44, but with metal braid covering for working pressures to 410 psi.

TYPE RF-54—Helically corrugated; sizes from ¼" through 2", I.D. for working pressures to 440 psi.

TYPE RF-55—Same as Type RF-54, but with metal braid covering for working pressures to 3100 psi.

To meet the growing demand for heavy duty stainless steel hose, Flexonics Corporation now offers new heavy wall Industrial REX-FLEX. Backed by unmatched experience in the manufacture of corrugated stainless steel, steel and bronze hose, the new Industrial REX-FLEX marks an important step forward in the development of corrosion-resistant hose that can stand the gaff of rugged industrial service, and still maintain maximum flexibility.

A complete range of flanged or screwed fittings may be used, attachment being made by silver brazing or atomic hydrogen welding.

Write for data sheets on Industrial REX-FLEX. For specific recommendations send an outline of your requirements.

TYPICAL APPLICATIONS FOR INDUSTRIAL REX-FLEX

- *Weigh tank connections*
- *Superheated steam*
- *Conveying corrosive gases and liquids*
- *High temperature connections*
- *Vibration connections*
- *Vacuum hose*
- *Fireproof connections*
- *Conduit*
- *Offset motions*
- *Continuous flexations*
- *Air ducts*
- *Exhaust connections, etc.*

WRITE FOR CATALOG

Industrial REX-FLEX is part of Flexonics' complete line of flexible metal hose. Other types are described in Catalog 132. Or see the Flexonics catalog in Sweet's File for Product Designers.

Flexonics *Corporation*

CHICAGO METAL HOSE DIVISION

1339 S. THIRD AVENUE • MAYWOOD, ILLINOIS

FORMERLY CHICAGO METAL HOSE CORPORATION

In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

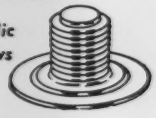
Flexon identifies products of Flexonics Corporation that have served industry for over 52 years.

Flexible metal hose

Expansion joints

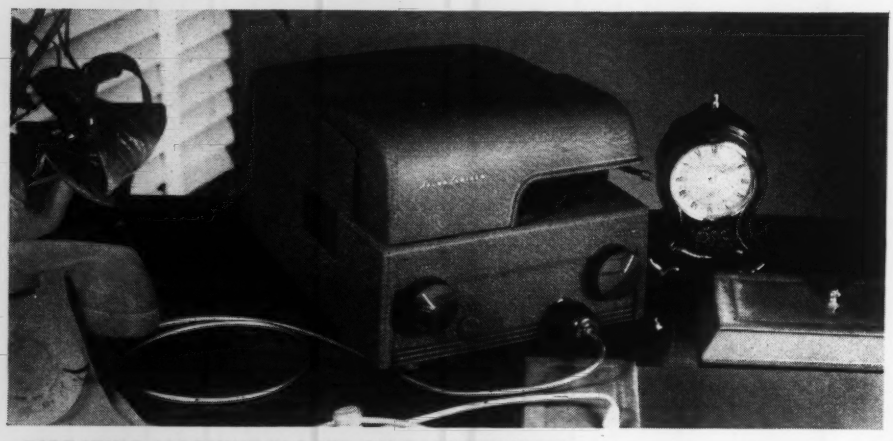
Aircraft components

Metallic bellows

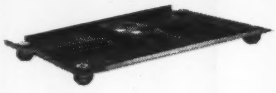


SHOCK - VIBRATION - NOISE

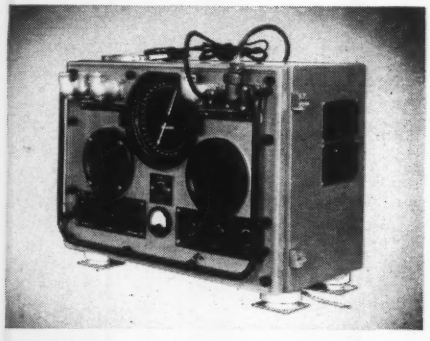
ISOLATION NOTES

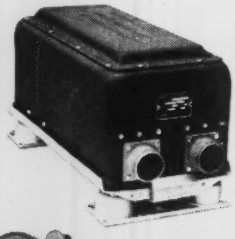


DICTATING MACHINE FLOATS ON BARRYMOUNTS — For noiseless operation, smooth, faultless playback, and the ultimate in protection against vibration and shock, Soundscriber Corp. chooses Barrymounts to support their new transcription unit. One more instance of how Barrymounts protect the performance of precision instruments. *Ask for data on Type 372 Barrymounts.*

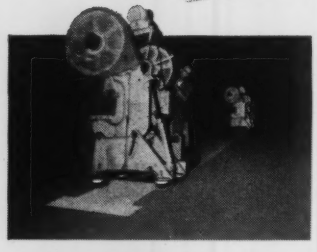


COAST GUARD DIRECTION FINDER GUARDED BY BARRYMOUNTS — Where reliability of performance is really vital, sensitive electronic equipment *must* be protected from shock and vibration. Raytheon Manufacturing Company says: "We find that the high quality and effectiveness of these mountings help us assure the famed reliability and excellence of our own products." *Ask for data on Type C-2000 Barrymounts.*





ALL-METL BARRYMOUNTS PROTECT AIRCRAFT RADIO COMPASS — For safe, assured, brilliant operation, at extremely high altitudes and over a wide range of temperatures, Lear uses Barry ALL-METL vibration isolators to support the sensitive components of their "Executive" radio compass. They say: "We have chosen the Barry product because we feel it is a superior product from the standpoint of providing greater trouble-free life". *Ask for data on Type M-44 Barrymounts.*



INDUSTRIAL MACHINERY MOBILIZED BY BARRYMOUNTS — For example: a production line of eight punch presses was shut down, moved 200 feet across the plant, and was producing parts again *in a total elapsed time of 23 minutes.* No lagging, no shimming, and no walking of the machines in operation — because they were mounted on the new Leveling Barrymounts. This is *machine-tool mobility* — a new idea to make new profits for YOU. *Ask for "LOOK — NO LAGGING!"*

The wide range of Barry products and the experience of Barry engineers can help you solve shock, vibration, and noise problems in any area of military or industrial activity. Call our nearby sales representative or write directly to us.

THE **BARRY** CORP.

722 PLEASANT ST., WATERTOWN 72, MASSACHUSETTS

SALES REPRESENTATIVES IN

Atlanta Baltimore Chicago Cleveland Dallas Dayton Detroit Kansas City
Los Angeles Minneapolis New York Philadelphia Phoenix Rochester
St. Louis San Francisco Seattle Washington, D.C. Montreal Toronto

Design Abstracts

few in a line of wound, cut-core reactors can be used, individually or in combination to build regulators having a wide range of power gains and power outputs.

Magnetic Amplifier Disadvantages: Like any other electrical component, magamps have certain limitations which must also be considered.

1. Magnetic amplifiers have finite minimum time delays depending on supply frequency. These time delays generally must be considered when designing regulated systems, unless high-frequency supply voltages are used.
2. Magnetic amplifiers require finite signal powers.
3. Magnetic amplifiers are sensitive to changes in supply frequency and voltages.
4. Single-channel magnetic amplifiers with dc output are inherently unidirectional in output. This is not always a disadvantage. Two-channel magnetic amplifiers are more complex, and there are limits to their application.
5. Single-channel magnetic amplifiers have finite minimum load currents. Magnetic amplifiers are temperature sensitive to a degree. This is not critical except for high-gain amplifiers subjected to wide temperature variations.

The many successful applications of magnetic amplifiers illustrate that the advantages are apparent not only to the regulating systems designer but to the ultimate user, since the disadvantages can be minimized by proper design and application.

From a paper entitled "Magnetic Amplifier Regulators" presented at the AIEE Winter General Meeting in New York, N. Y., January, 1954.

Developing New Products From Prior Patents

By George V. Woodling

IN DEVELOPING a new product for a new field, a company has three alternatives. As a first plan, the company may assign the task of designing the new product to

its present engineers and let them experiment with the new product in the hope that they might come up with a new design of improved features. Experience shows that this method — turning the engineers loose in a new field without a planned program of research —places them at a disadvantage, although there is always the exceptional case.

As a second alternative, the company may hire a top-ranking engineer from another company already engaged in the new field with the expectation that the new engineer with his wealth of technical knowledge and know-how can design the new product with the greatest of ease at a minimum of experimental costs. The difficulty with this plan is that the new engineer is apt to direct the lines of the new design along lines similar to the product made by his former company. In this event, little is gained since the new product would be devoid of additional patentable values which are so necessary when a company enters a new field.

As a third alternative, the company may obtain the technical knowledge and know-how by making an exhaustive search in the Patent Office, to the end that the engineers, even though they are new or fresh to the field, can develop a new product by avoiding the pitfalls encountered by previous inventors as recorded in the large list of patents in the Patent Office. Under this plan, the engineers are not at a disadvantage nor are they apt to fall into an engineering "rut" as would be the case where an engineer is hired from another company. Thus, patents serve as a "know-how tool" to collect prior art knowledge of the subject.

Know-how Tool: At our company, we adopted the third plan in developing new hydraulic tube fittings with alloy steel sleeves. In the early stages of our development, we examined and digested more than 200 patents on tube fittings of all kinds. In these patents we learned not only the good

(*Continued on Page* 328)

COMAR RELAYS...

for countless industrial and military applications...

Aircraft Controls
Business Machines
Radar Systems
Electric Cameras
Guided Missiles
Communications
Transcribers
Coin Machines
Electric Toys
Test Panels
Computors
Alarm Systems
Electric Timers
Tape Recorders
Generator Controls
—hundreds of others

Comar relays have consistently been "approved" by leading designers and manufacturers because of their superior performance, dependable operation. Comar relays are custom-engineered to exact specifications, job-tested and job-proved for top efficiency, quality constructed for utmost reliability. If you use relays, it will pay you to contact Comar. Our experienced engineering staff, plus huge manufacturing and sealing facilities, will save you time and money. Send for catalog.

Comar ELECTRIC COMPANY
3349 ADDISON STREET
CHICAGO 18, ILLINOIS

RELAYS • SOLENOIDS • COILS • TRANSFORMERS • SWITCHES • HERMETIC SEALING

NOW READY—an authentic

Gilmer "TIMING"®

"TIMING" BELT APPLICATIONS

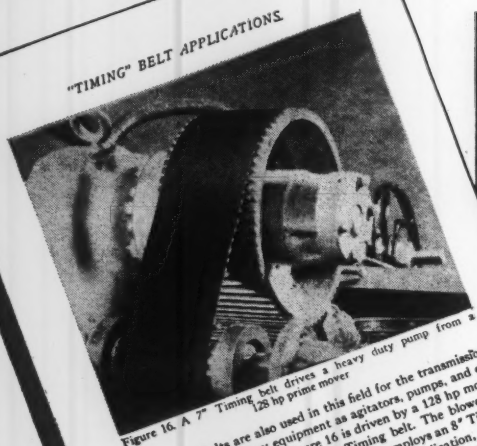


Figure 16. A 7" Timing belt drives a heavy duty pump from a 128 hp prime mover

Timing belts are also used in this field for the transmission of power to such heavy equipment as agitators, pumps, and exhaust fans. The pump in Figure 16 is driven by a 128 hp motor through a 7" wide "heavy duty" Timing belt. The blower in Figure 17 is driven by a 140 hp motor and employs an 8" Timing belt. Had a V-belt drive been used on this application, 21 C-section belts would have been required. It will be noted that, in ...-in. photograph, the flanges have been removed from the drive ...8. This sani-...ol unit. Tim-...efore and 3:1

"TIMING" BELT WIDTH CALCULATIONS

use of an application factor somewhat less than 1.0, thereby decreasing rather than increasing the nominal horsepower of the drive.

DETERMINING BELT HORSEPOWER RATING

Two Calculations Necessary

The horsepower which a Timing belt of any given construction can transmit is determined by its speed and width. The belt-width required for any specific drive is, in turn, governed by two considerations: the tensile strength of the belt and the number of the belt's teeth in full mesh with the grooves of the smaller pulley. Both should be calculated and the final determination of belt width should be made on the basis of the *lower* of the two horsepower-per-inch-of-width ratings.

In most cases the *tensile strength* rating will be the basis for determining belt width. However, when a high-ratio drive produces a small arc of contact between the belt and smaller pulley, the *working tooth strength* rating will probably determine belt width

NON-STANDARD D...

pulleys up to 3" diameter.

Because of the horsepower, a P5 b... used. Assume a 2" pulley diameter. Appl...

$L = 2 \times 4.375 + 3.14 \times ...$

$= 8.75 + 6.28 = 15.03$...

Nearest belt length is 15.00"; pitch is 0.234...

$$N = \frac{2 \times 3.14}{0.234} = 26.8$$

We shall let $N = 27$. (Since the following ... exact values, we shall carry our calculations ... for greater accuracy.) Formula (2) gives ... diameter.

$$D = \frac{27 \times 0.2344}{3.1416} = 2.0145"$$

This value substituted in Formula (13) enable... the exact center distance.

$$C = \frac{15.000 - (3.1416 \times 2.0145)}{2}$$

$$= 4.336$$

This is well within the 1/8" tolerance specified for t... distance.

Fixed-Center Drive: Ratio Other Than 1:1

Timing belts are particularly well suited to driv... take-up or adjustment between pulley centers is pra... their elongation in service is so infinitesimal that it can... The chances are quite small that such a drive can b... actly (i.e., within 0.001" of the desired center distance)... of any combination of available belts and pulleys. Ne... it is worth while to check on this possibility before deci... a special belt and special pulleys will be required. Note, ... that any calculation using Formula (6), which yields ... for L that is no more than 0.1" from an available belt... should be rechecked using the Coinvolute Method (Fo...

49

STANDARD STOCK PULLEYS

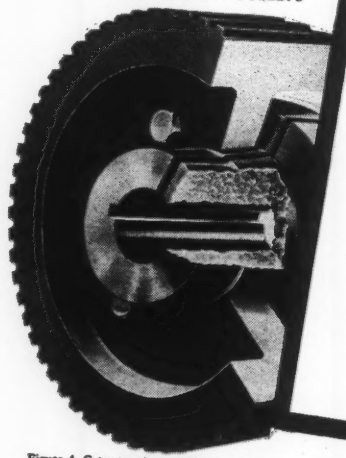


Figure 4. Cutaway view of Timing belt pulley equipped with "QD" hub.

pulleys equipped with "QD" hubs will be found in the Appendix on page 162.

When ordering Standard Timing belt pulleys, it is necessary to specify the sizes of the shafts on which they are to be mounted, *in addition* to the pulley code symbols. This applies regardless

29

"TIMING" BELT PULLEYS

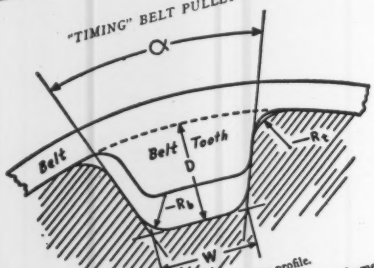


Figure 2. Pulley groove profile.

of the belt teeth. Where zero backlash is a requirement, the Timing belt manufacturer should be asked to furnish pulleys or drawings having special dimensions to provide it.

Groove profile dimensions of Standard pulleys are as follows:

	Light duty 3/8" *pitch*	*Heavy duty* 1/2" *pitch*
Included angle, α	40° ± 3°	40° ± 3°
Groove depth, D	0.104" to 0.107"	0.150" to 0.153"
Bottom width, W	0.115" to 0.125"	0.145" to 0.155"
Top radius, R_t	0.031" to 0.036"	0.046" to 0.051"
Bottom radius, R_b	3/64" max.	1/16" max.

The correct groove profile dimensions to be used in manufacturing pulleys for use with the various Non-Standard Timing belts will be found in the tables in the Appendix.

Pulley Materials

Timing belt pulleys have been made of practically every material used in the manufacture of gears—steel and cast iron

16

NEW YORK BELTING & PACKING CO. • Founded 1846

NYB&P

NEW YORK BELTING & PACKING CO. 1 Market St., Passaic, N.J.

America's Oldest Manufacturer of Industrial Rubber Products

200-page designer's handbook on the

BELT DRIVE

JUST PUBLISHED

$3.50 POSTPAID

"TIMING" BELT DRIVE ENGINEERING HANDBOOK

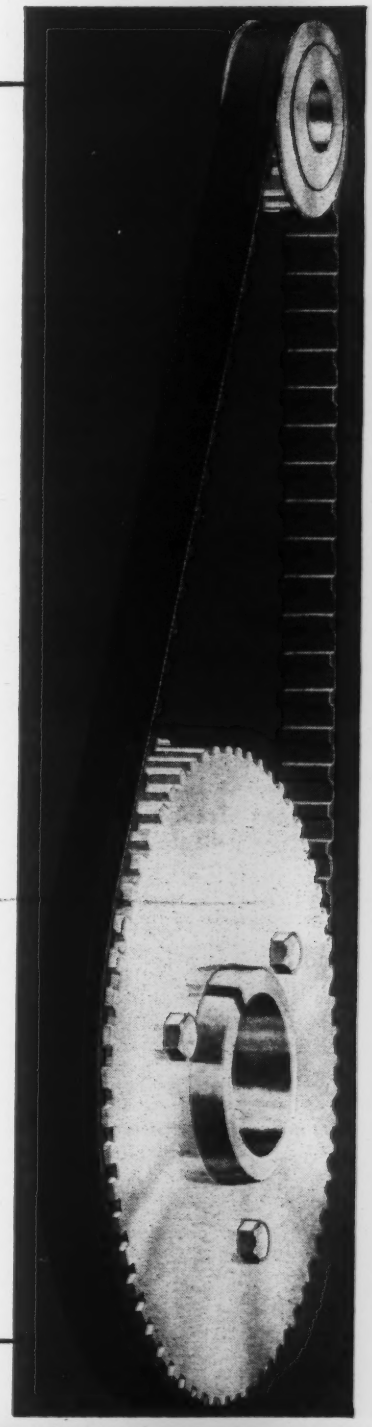
Edited and Produced by McGraw-Hill Book Co.

Introduced on a limited scale only eight years ago, the Gilmer "Timing" Belt Drive is now so widely accepted the list of its users reads like a "Who's Who" of machinery manufacturers. Well over a million of these super-efficient, non-slip belt drives are used daily to transmit loads from 1/100 to 300 HP as well as to maintain precise synchronization between two or more shafts.

Now, even more firmly establishing the "Timing" Belt as a new and proved power transmitting medium, we are proud to announce the production by McGraw-Hill of an authoritative engineering handbook containing all facts and formulas involved in calculating and designing both belts and pulleys for all types of "Timing" Belt Drives.

This 200-page book, written by the "Timing" Belt's inventor, is available through our Gilmer "Timing" Belt Division, Philadelphia 35, Pa., at $3.50, postpaid anywhere in the United States. The typical pages at left, reduced from their 5½" by 8½" size, illustrate the lucid, semi-technical style in which every phase of drive design and construction is discussed.

If you design power-driven machinery of any kind, a copy of this handbook should be at your finger tips. Use the handy order form below. You need send no money with your order. We'll gladly bill you—or your firm—on 30-day terms if you so indicate.



ORDER FORM

Gilmer "Timing" Belt Division
New York Belting & Packing Co., Tacony, Philadelphia 35, Pa.

Please forward.....copies of the "Timing" Belt Drive Engineering Handbook at $3.50 per copy, postpaid.

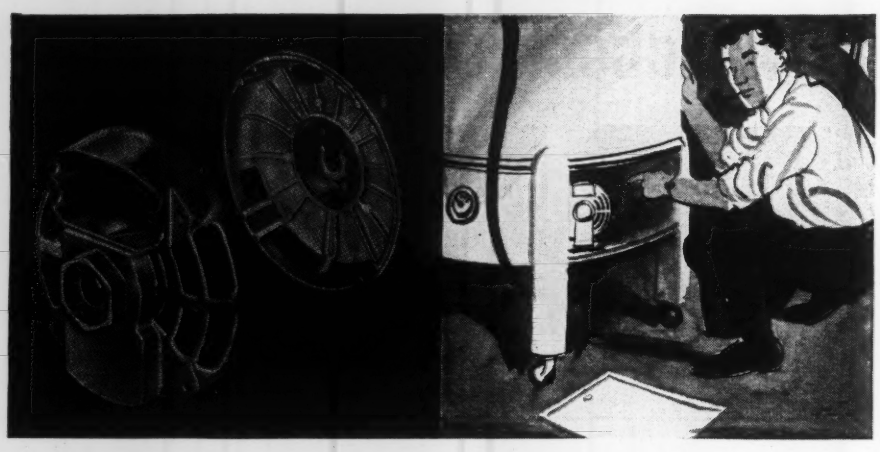
☐ Payment Herewith ☐ Bill me ☐ Bill my firm

Name.....

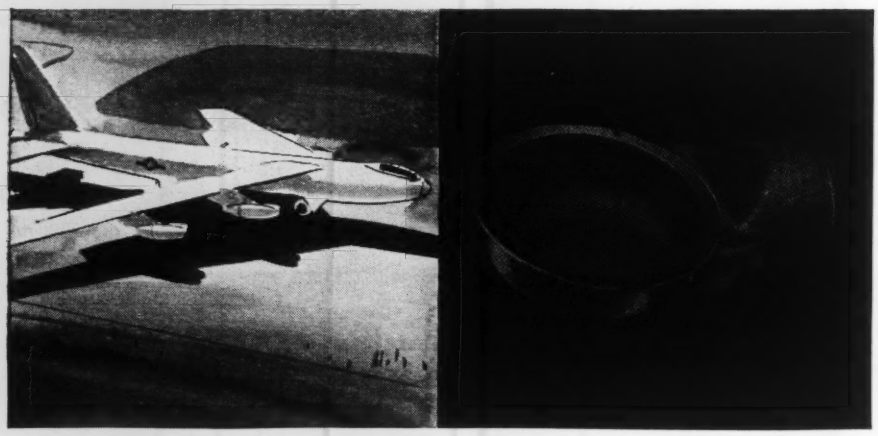
Firm.....

Address.....

(Advertisement)



Washing Machines and Jet Planes



Thompson Precision-Engineers Light Metal Castings for All Industry

MILADY'S washing machine and the jet plane overhead have one thing in common—both count on Thompson. For, in each, you'll find precision-engineered castings produced by Thompson's versatile Light Metals Division.

Among several parts produced by Thompson for use in washing machines and other appliances are end frames for electric motors. And Thompson's exacting light metals engineers have produced numerous parts for the speedy jets —including a die cast air connector, used for cooling an electric generator.

These are but two of the many light, strong, durable castings designed, developed, and manufactured by Thompson. Behind today's versatile light metals operations are over 50 years experience in research and manufacture of precision parts, enabling Thompson to offer its facilities to all forms of industry.

Thompson is now producing light metal castings for such diversified products as buses and garbage disposers; tractors and outboard motors; automobiles and industrial engines; ice scoops and aircraft engines.

Regardless of your product, if you use castings, Thompson's creative engineers will gladly show you where and how you can simplify your operations and save on costs with Thompson's Light Metals Castings.

For a detailed description of the Thompson Light Metals facilities which are available to you, send for your free copy of "Creative Castings". Just write to Dept. MD-4, Light Metals Division, Thompson Products, Inc., 2269 Ashland Road, Cleveland 3, Ohio.

You can count on

Thompson Products

LIGHT METALS DIVISION
2269 Ashland Rd. • Cleveland 3, Ohio

Design Abstracts

(*Continued from Page 325*)

features, but also the bad. We knew what to avoid before we started. As each patent was examined, we learned why each prior art tube fitting was deficient. The knowledge which we acquired from these patents snow-balled as each subsequent patent gave us a larger wealth of technical knowledge than could possibly have been obtained by hiring a top-ranking engineer from a company already in the tube-fitting business.

Idea-generating Tool: Besides functioning as a know-how tool for collecting prior art knowledge, patents may be used as an additional tool to generate ideas which lead to new inventions. There is no specific name for this "idea-generating tool," but here is how it works. It comes about by respecting or honoring the claims of

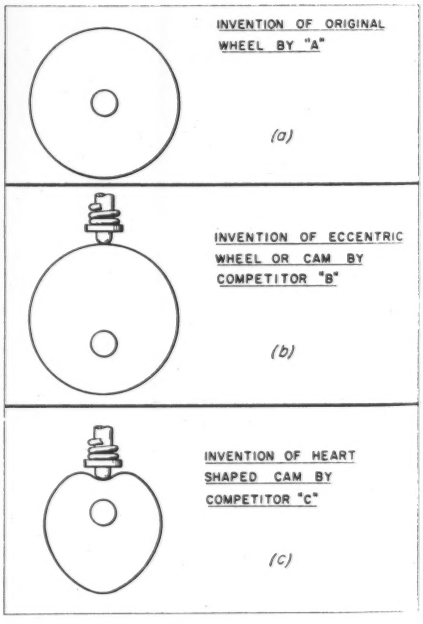


Fig. 1—Steps employed to "super invent" from prior patents

the prior patents of others rather than disrespecting them.

The purpose of the claims in a patent is to define the boundaries of the invention which is protected. The protection afforded by a patent is not defined or measured by the patent drawings or description. These constitute a dictionary for

the claims and are used to explain the true nature and meaning of the claims, but it is the claims which stake out the boundaries for the invention which is protected.

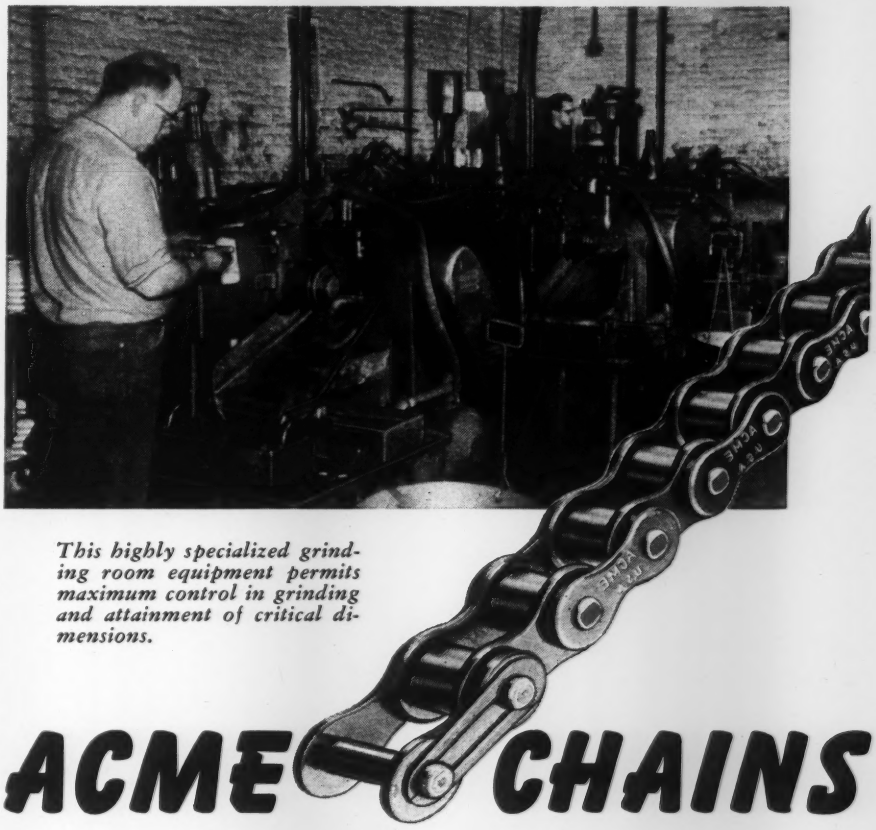
The competitor may treat the patent claims in either one of two ways. First, he may disregard the patent and litigate its validity and noinfringement. Such litigation ordinarily entails a considerable amount of expense and time. Secondly, the competitor may honor the patent claims and thus consider them as presenting a challenge to his inventive faculty to create new designs which lie outside of the fenced-in property of the patent claims. A new creation thus invented becomes a noninfringing device when manufactured, sold and used by the competitor. It is to be pointed out that the creation of an invention conceived by means of this idea-generating tool may be described as "superinventing."

Designing Around Patents: Two practical applications of the idea generating tool are shown in *Fig.* 1. In the invention of the original wheel, *Fig.* 1*a*, "A's" claim covers and defines the structure and includes the words "a circular body having a central axis." Competitor B, weighing the words of limitation, "superinvents" a wheel, *Fig.* 1*b*, with an eccentric axis, which is non-infringing. It is this procedure of honoring the original claim and designing around it which leads to the making of many worthwhile improvement inventions. Competitor C finds that he cannot manufacture and sell concentric or eccentric wheels. Therefore, he produces a heart-shaped cam, *Fig.* 1*c*, which is free of infringement.

Most cases in actual practice are not so simple as depicted in these illustrations of the wheel and cams, but they do show how inventions may be made solely by the method of respecting prior patent claims and designing around them. It is this latter technique which constitutes the idea-generating tool used by most of the prolific inventors.

The test for designing around

No. 4 - Precision Operations in the Manufacture of ACME Chains



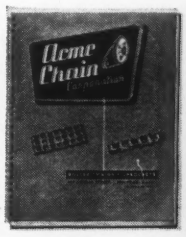
This highly specialized grinding room equipment permits maximum control in grinding and attainment of critical dimensions.

ACME CHAINS

a dependable source of supply

The ACME line of roller chains include all American standard sizes of machine finish steel roller chain with standard attachments for these chains, the heavy series of standard pitch chains, the extended pitch series of chain attachments for same. ACME also builds special attachments that may be required for special purposes in various lines of industry and for the conveying and elevating of materials; also a line of cable or leaf chains.

Want special type chains? Write or phone Holyoke 2-9458, our Engineers will be glad to help you.



Write Dept. 6G for new illustrated 76 page catalog on use and application of roller chains and sprockets.

Acme Chain Corporation
HOLYOKE
MASSACHUSETTS

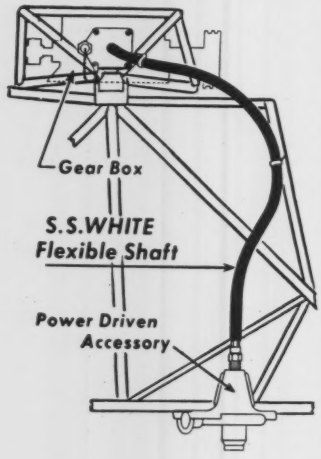
THE PROBLEM

TRANSMITTING POWER THROUGH CROWDED AREAS

An aircraft designer wanted to convert a standard helicopter over for "crop-dusting" service. He planned to do this by mounting an insecticide pump on the bottom of the fuselage and by driving the pump from the plane's accessory gear box. However, intervening struts, frames and other parts made it both impossible and costly to install a direct drive between the gear box and the pump. That's why he chose —

THE LOW-COST SOLUTION

AN S.S.WHITE POWER DRIVE FLEXIBLE SHAFT



As the illustration shows, a single flexible shaft did the job. In addition to saving parts, the shaft was easily installed — needed no alignment — and required no adjustments after installation. Even though your power drive problems may be different, the chances are you'll be able to realize similar savings with S.S.White flexible shafts. Their simplicity, adaptability and dependability often result in improved designs and lower costs. Our engineers will be glad to cooperate with you in working out any application.

Get the Full Flexible Shaft Story

The 256-page Flexible Shaft Handbook will show you how flexible shafts can be used to improve design and lower costs. A free copy will be sent if you write for it on your business letterhead.

THE S.S.White INDUSTRIAL DIVISION
DENTAL MFG. CO.
Dept. 4, 10 East 40th St.
NEW YORK 16, N. Y.

Western District Office • Times Building, Long Beach, California

Design Abstracts

prior patent claims may be stated as follows: There is no infringement if the subsequent device is so constructed that it omits at least one of the limiting provisions of the prior claim. The main thing is to make the new invention lie outside the fence which protects the prior invention. This test is called the "omission test" and holds true unless the omitted part has been replaced by an equivalent part or component.

Substitutions which are required by the patent laws to constitute noninfringement must not be of a trifling nature, but should be such substitutions as will affect the real life and operation of the new design. A competitor who endeavors to design around prior patent claims is treading on dangerous ground if his ingenuity will permit him to make nothing more than a trifling change over the prior claims, because he runs the risk of defeat when sued for infringement. A competitor must exercise great imagination—and this constitutes the real challenge presented in the practice of patent law.

It is to be pointed out that when a competitor designs around the claims of a prior patent, the structure produced thereby is only free of infringement of that particular prior art patent. In actual practice, it is not uncommon for a competitor to be required to design around a collected group of prior art patents rather than one. Therefore, the task of designing around prior art patents not only entails imagination, but also persistence, painstaking work and many long hours.

Avoiding Infringement: Sometimes a competitor feels that he can avoid a charge of infringement if he obtains a patent upon his own device covering the additional features that his device possesses over a prior patented device. This is an erroneous idea because a patent does not give the inventor the right to make, sell and use his own device if it infringes a prior patent. The grant of a patent gives the inventor only the right to exclude others from making, selling

and using his device.

Improvement Patents: It must not be understood from the foregoing discussion that it is of no importance to obtain improvement patents. The secret of breaking into a well-established manufacturing field which is dominated by broad patents is to develop genuine improvement patents. As the broad patents expire, the improvement patents then become primary in the industry, which gives the owner of the improvement patents a material advantage since he will now dominate the field.

Should the owner of the improvement patents desire to enter the manufacturing field without waiting until the broad and dominant patents expire, he is in a good position to do so because he can bargain with the owner of the broad patent for a license to enter the field. One of the strongest inducements for obtaining such a license is that the owner of the improvement patents can offer in return a license under his improvement patents and thereby give the owner of the broad patents the right to use his improvements. In this manner, improvement patents become the basis for progress.

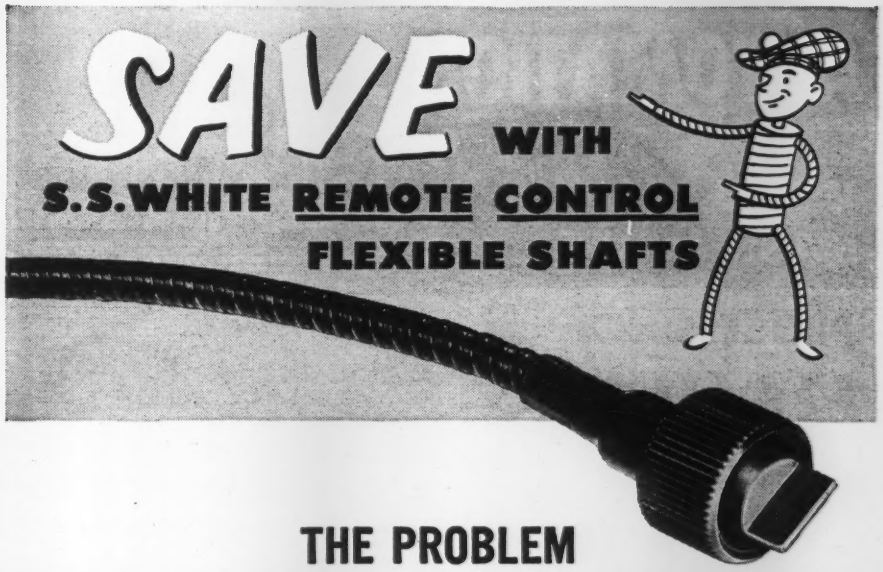
From a paper entitled "New Applications and Designs for Patents" presented at the 11th Annual Machine Design Conference sponsored by the Cleveland Engineering Society in Cleveland, O., February, 1954.

Sealing Elements for Rocket Application

By H. Davies

Reaction Motors Inc.
Rockaway, N. J.

SEALING problem encountered in rocket engines may seem to be an insignificant feature of design, but difficulties with seals and joint applications occur with sufficient frequency and persistency to make this an important design aspect. The range of operating conditions and methods used for sealing pur-



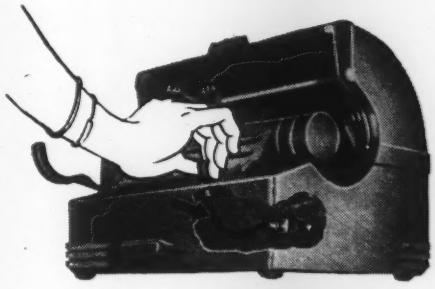
THE PROBLEM

PROVIDING AN INEXPENSIVE RIGHT ANGLE COUPLING

One of the features of the voice transcriber shown below is a manual control knob for regulating the voice playback speed. The designer of the unit wanted to locate this speed control knob where it would be convenient to operate and where it would be hidden from view when the cover of the machine was closed. This meant mounting the control knob shaft and the speed regulator shaft at right angles to one another. After considering various ways of coupling the two shafts, the designer chose

THE LOW-COST SOLUTION

AN S.S.WHITE REMOTE CONTROL FLEXIBLE SHAFT



With an S.S.White Flexible Shaft, the designer was able to effect a simple, easily installed coupling which met all requirements of the application. No extra parts were needed, assembly time was kept to a minimum and alignment problems were eliminated. And, as the firm reported, the shaft assured the delicate sensitivity of "feather-touch control."

It's savings like these that make S.S.White flexible shafts a "must" for your own remote control applications. Investigate their use today. The cooperation of S.S.White engineers is always available without obligation.

Send for this Valuable Handbook

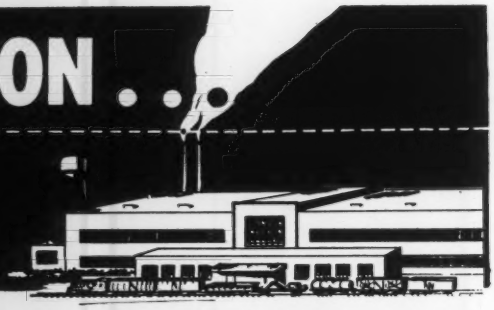
The S.S.White Flexible Shaft Handbook provides comprehensive data on flexible shaft selection and application. A free copy is yours if you write for it direct to us on your business letterhead.

THE S.S.White INDUSTRIAL DIVISION
DENTAL MFG. CO.
Dept. 4, 10 East 40th St.
NEW YORK 16, N.Y.

Western District Office • Times Building, Long Beach, California

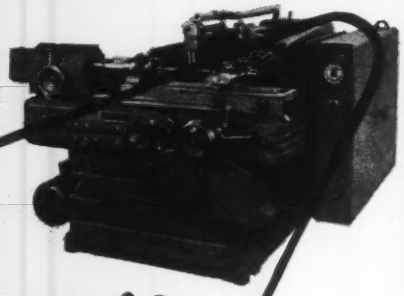
AUTOMATION . . .

IF YOU MANUFACTURE



PROCESSING

MACHINES



ADD EAGLE TIMING OR COUNTING

THE MICROFLEX COUNTER insures greater precision at reduced cost on this thread grinder by automatically redressing the grinding wheel after a preset number of operations.

The Microflex Counter is not a totalizing instrument. It automatically operates contacts after a preset number of electrical impulses and is spring reset. Modernize your machines for greater efficiency with EAGLE Timers and Counters. Eagle sales engineers will assist you without obligation. Write today for literature or send us your control problems.

Industrial Timers by EAGLE

EAGLE SIGNAL CORPORATION
MOLINE, ILL.

Design Abstracts

poses is broad so only the more common ones will be considered in this discussion.

Satisfactory static seals for rocket applications must embody the following characteristics:

1. Low volume and weight.
2. Simplicity and economy in production.
3. Reproducibility, both in manufacture and installation.
4. Positive sealing at all service pressures.
5. No periodic servicing requirements, such as torqueing of nuts.
6. Joints must not trap fluid.

Zero leakage under a wide range of thermal and dynamic conditions is a highly desirable feature and is mandatory when dealing with highly corrosive or toxic propellants. In general, it is more difficult to seal at low pressures than at high pressures due to the small forces available. This implies the use of a joint design in which either the mechanical parts or the joint material has a large degree of resiliency.

Metal-to-Metal Seals: Flared-joint metal-to-metal seals made to the AND 10056 standard are suitable for use with all common rocket fuels, monopropellants and oxidizers. Their use in the acid oxidizers for long-term applications cannot be recommended because of corrosion in the cavity between the flare and the nipple; however, they are satisfactory when used with acids for short-term operation. Above a 1-inch tubing size, flared joints become bulky and heavy and it is common practice to adopt flanged joints for the larger size range. In some of the early 6,000-pound engines, metal-to-metal seals in the form of lapped conical faces were used for valves in liquid oxygen service. These proved to be satisfactory from an operational point of view but the expense of making the lapped seal was an undesirable feature.

Semiresilient Seals: Gasket-type joints have been used in a wide variety of rocket applications including propellant lines and hot-gas joints on thrust chambers. An undesirable situation exists when

EATON

DYNAMATIC

®

EDDY-CURRENT ROTATING EQUIPMENT

is Solving Problems for Every Major Industry

Wherever a requirement exists for an adjustable speed clutch or brake under precise control, operating from AC power, you will find Dynamatic Equipment. In practically every major industry — paper, rubber, automobiles, aeroplanes, machine tools, metals, chemicals, cement, lumber, ceramics, petroleum, plastics, and in leading research laboratories, Dynamatic Equipment has been found the ideal solution to difficult problems.

Dynamatic engineers will be glad to work with you in specifying the proper Dynamatic Equipment to meet your requirements.

There are Dynamatic representatives in most principal cities. Contact your local representative or write direct to the factory, Kenosha, Wisconsin.

Write for your copy of Bulletin GB-1, which describes and illustrates the basic Dynamatic units.

DYNAMATIC®

DIVISION EATON MANUFACTURING COMPANY

KENOSHA, WISCONSIN • General Offices: Cleveland, Ohio

Over 400 Standard Models of
"LONG-LIFE" PUMPS

Servicing pump failures
Down-time on equipment } = $$

That's why **rugged dependability** is built into PIONEER AND ROLLWAY pumps—insuring month after month of continuous, trouble-free operation.

And You Save On----

- **PUMP COSTS** (capacity-tested before shipment)
- **POWER COSTS** (high efficiency)
- **INSTALLATION COSTS** (over 400 *standard* models to "fit" your job)
- **SPACE** (no need for "oversize" pumps)

For Widest Range of Applications

- **Lubricants and coolants to abrasive liquids**
- **Mount above or below liquid level**
- **External or submerged**
- **All conventional methods of mounting and coupling**
- **Use your motor or ours**

Ask for complete Manual & Catalog #46

Headquarters
14300 Tireman
Detroit 28, Michigan

(FACTORY
Paris, Kentucky)

DETROIT HARVESTER Co.
PIONEER PUMP Division

Design Abstracts

soft gaskets are used in a joint design and interposed between flanges because loading conditions on the flange bolts vary as internal pressure is applied. Naturally, this disadvantage does not apply to O-rings where stiffness of the ring is small in comparison with that of the flanges and the flange faces are butted. Teflon or Kel-F are the most desirable gasket materials in conjunction with rocket propellants, but both of these suffer from the disadvantage that at the unit stresses which are necessary for sealing purposes severe creep of the gasket material occurs. Thus, it is necessary to provide a large degree of flexibility in the flanges so that sealing may still be maintained under such conditions.

Extreme Temperature Seals

In addition to the sealing of rocket propellants at room temperatures, a need exists for seals that can be used with extreme low-temperature propellants such as liquid oxygen (−297 F) and also with hot propulsion gases at temperatures from 1000 to 2200 F. Flat gaskets do not provide adequate means of sealing at liquid oxygen temperatures because of the large amount of differential expansion in the gasket material. Also, while many materials such as asbestos will withstand the high temperatures involved in hot gas lines, they have poor mechanical properties and are generally troublesome in service.

It has been found that one type of commonly used commercial gasket makes a satisfactory installation in both of these environments; this is the spirally-wound fillet gasket, such as the Flexitallic. This gasket consists essentially of a thin strip of formed material, usually stainless steel, with asbestos or a plastic material in the interstices. Such gaskets are usually retained in a butted type design and the steel laminates are strained elastically in the loaded position. This type has the advantage that its axial stiffness may be varied by altering the tension during the manufacturing process; thus, it is easy to design a gasket with the stiff-

Vibration testing made easier

Electronic component under test at Eclipse-Pioneer division of Bendix Aviation Corporation.

with the help of MB equipment like this

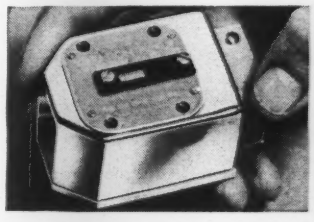
Do you have to vibration-test your product to meet military specifications? Want to apply shake-testing to improve product design or to control quality? If so, do what many leading companies have done—enlist the help of MB.

First, you get the right equipment. MB offers a *complete* line of vibration exciters from 10 pounds force all the way to the largest developed today—10,000 pounds! All are quality built to stand up and do the job right to specifications. Electromagnetic in operation, they're easily and quickly adjusted for force and frequency. And, second, you get the benefit of MB's wide experience in applying this relatively new and valuable technique for product improvement.

Among the well known companies working with MB products, Bendix Aviation Corporation's Eclipse-Pioneer division is outstandingly equipped with *several* MB Vibration Exciters. The photograph shows one—MB Model C-25, rated at 2500 pounds of force—vibrating an electronic component to insure dependability under severest conditions. Such testing can uncover, in minutes, trouble that might take months to develop.

VIBRATION PICKUP ANOTHER USEFUL TESTING TOOL

When you want to detect vibration and determine its nature, you'll want an MB Vibration Pickup. While the pickup detects even slightest vibratory motion, it was built for grueling service as well. Model 122 withstands temperatures up to 500°F.



Control panels for all MB shakers, as in the photo above, can be furnished with MB Vibration Meter for use with pickup. This meter gives direct velocity, acceleration and amplitudes of the picked-up vibration.

Bulletins you'll welcome

How to calibrate vibration pickups to 2000 cps—Bulletin C-11-3 reviews the subject comprehensively. Bulletin 1-VE-3 tells all about MB Vibration Exciters. Write for them.

THE MB MANUFACTURING COMPANY, INC.
1060 State Street, New Haven 11, Conn.

HEADQUARTERS FOR PRODUCTS TO INDUCE VIBRATION...TO MEASURE IT...TO ISOLATE IT

Quality based on METALLURGICAL LEADERSHIP • •

CHIEF SANDUSKY
CENTRIFUGALLY CAST, NON-FERROUS RINGS, ROLLS, LINERS, TUBES, BUSHINGS, BEARINGS, and SLEEVES.

Chief Sandusky knows that every day it must justify the reputation it has earned—since 1907—as the authority on non-ferrous centrifugal castings. Advanced research facilities is an important reason why users of non-ferrous cylinders have learned to depend on Chief Sandusky as their source of supply.

Not only do specialized metallurgists rigidly control the quality of these centrifugal castings, they are alert scouts and guides along the trail to improvements. And they welcome the challenge of metallurgical problems to solve so that they can apply their skills to produce the right answer —the satisfactory solution.

Beginning with research laboratories and all down the line through highly specialized production processes—refined from years of gaining knowledge through experience —every step of the way proves that the best in centrifugal nonferrous castings bear the name, **"Chief Sandusky."**

C. M. Lovsted & Co., Seattle, Wash. Tyne Bros., Birmingham, Ala.
Cordes Bros., San Francisco and Long Beach, Calif.

SANDUSKY FOUNDRY and MACHINE CO.

615 W. Market Street Sandusky, Ohio

Design Abstracts

ness required by a particular joint application. Such joints have been found to give excellent service in high-temperature and high-pressure rocket applications when a gasket made of AISI 309 steel filled with asbestos is used. Gaskets of this type constructed from the austenitic stainless steels with Teflon fillers have proved to be satisfactory for service with liquid oxygen.

Asbestos-filled gaskets, jacketed in aluminum or copper and similar in construction to spark-plug gaskets, have also had a limited application to rocket engine use but suffer from the disadvantage that relaxation and permanent deformation usually occur under successive tightening conditions. Metal O-rings have also become popular recently. These require relatively rigid attachments but are convenient because of their extremely small cross-sectional size, which may go down to 1/32-inch. Their use includes both room temperature and high temperature applications.

Resilient Seals: O-ring resilient seals may be obtained in a wide variety of elastomers for compatibility with the entire range of rocket fuels. The rocket oxidizers, however, present problems in that there are no known elastomers which are completely satisfactory with either nitric acid or hydrogen peroxide. Similarly, the differential contraction problems associated with the use of liquid oxygen make it extremely difficult to design O-ring joints for this propellant. Successful applications have been made in which a large degree of initial pinch is given to the O-ring and rings of the smallest possible cross-section are used. However, accurate design data for this type of application are lacking.

The nature of resilient seals makes them unsuited to long term storage applications where vapor pressures are involved. Requirements of this nature commonly call for zero leakage over a period of one year and such is not possible with O-rings in any presently used elastomers.

From a paper entitled "Aspects

of the Design and Fabrication of Liquid Propellant Rocket Engines" presented before the American Rocket Society at the 1953 *ASME Annual Meeting in New York, N. Y., December,* 1953.

Critical Design Factors in Relay Selection

By J. G. Crockett

Government and Industrial Div.
Philco Corp.
Philadelphia, Pa.

When the equipment designer selects a relay, he is usually guided by the following considerations:

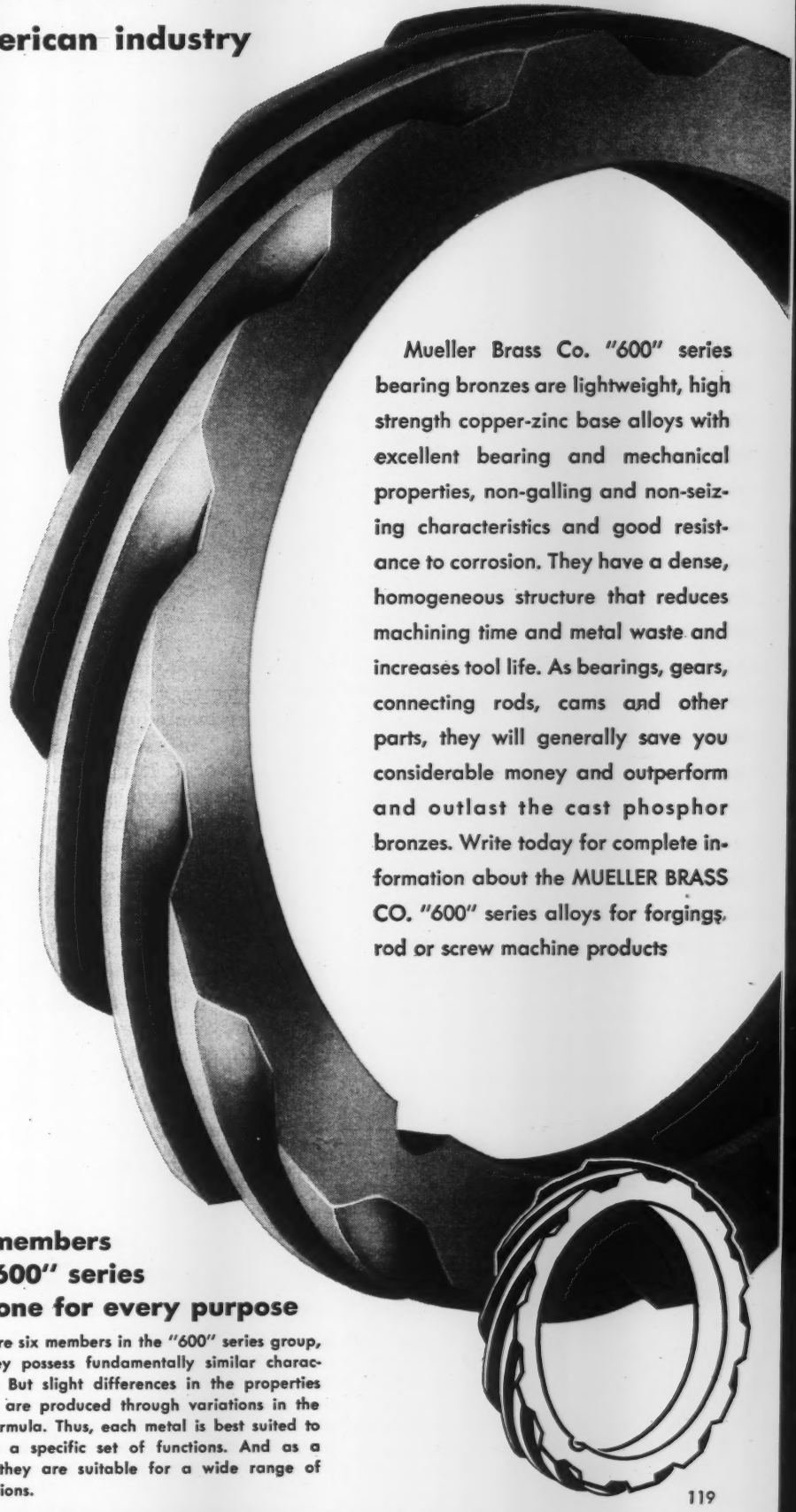
1. Circuit requirements—performing required switching under specified conditions
2. Life and reliability
3. Environmental factors
4. Space and weight requirements
5. Availability
6. Cost

Circuit Requirements: Relays are deceptively simple and, furthermore, their operation is mechanically obvious. Even the experienced design engineer has a tendency to be more absorbed in circuitry and to relegate relays to the category of "standardized" components with resistors, capacitors, etc. Also, the designer finds that the use of a relay enables him to accomplish results that would be rather difficult to obtain by other means and he often employs considerable ingenuity in evolving unusual relay requirements.

This is a field in which invention often becomes the mother of necessity. Of course, it must be borne in mind that the designer is subject to many antithetical pressures and there are many cases where time is the governing factor. Often the design engineer is experimenting and has no clear-cut idea of all the interlocking factors that will ultimately be involved but needs a relay of some sort to get started.

Certain things must always be known, however, and these are the kind and value of current or voltage to operate the relay and the kind and value of current or voltage to be switched. Usually the de-

MUELLER BRASS CO.
600 SERIES BEARING ALLOYS
FORGINGS • ROD • SCREW MACHINE PRODUCTS
proving their quality throughout
American industry



Mueller Brass Co. "600" series bearing bronzes are lightweight, high strength copper-zinc base alloys with excellent bearing and mechanical properties, non-galling and non-seizing characteristics and good resistance to corrosion. They have a dense, homogeneous structure that reduces machining time and metal waste and increases tool life. As bearings, gears, connecting rods, cams and other parts, they will generally save you considerable money and outperform and outlast the cast phosphor bronzes. Write today for complete information about the MUELLER BRASS CO. "600" series alloys for forgings, rod or screw machine products

six members
of "600" series
. . . one for every purpose

There are six members in the "600" series group, and they possess fundamentally similar characteristics. But slight differences in the properties of each are produced through variations in the basic formula. Thus, each metal is best suited to perform a specific set of functions. And as a group, they are suitable for a wide range of applications.

119

MUELLER BRASS CO. PORT HURON 15, MICHIGAN

Consult LITTLEFORD First . . .

FOR WELDMENTS FABRICATED BASES SUB-ASSEMBLIES

You'll find Littleford's experience in precision fabrication of sheet and plate steel makes difficult jobs both easy and economical. Our engineers, skilled craftsmen and complete facilities assure you accuracy, economy and modern design. We know how to provide strength that withstands shock, strain and vibration. Littleford scientific operations also give you greater adaptability with less weight and bulk in steel assemblies, machine bases, machine parts, special parts, frames, guards, mounting structures, etc. And it actually costs you less to get the best, from Littleford's dependable fabrication. Send us your blueprints for estimate.

FABRICATORS OF PLATE AND SHEET METAL PRODUCTS FOR INDUSTRY SINCE 1882

LITTLEFORD

LITTLEFORD BROS., INC.
424 E. PEARL STREET
CINCINNATI 2, OHIO

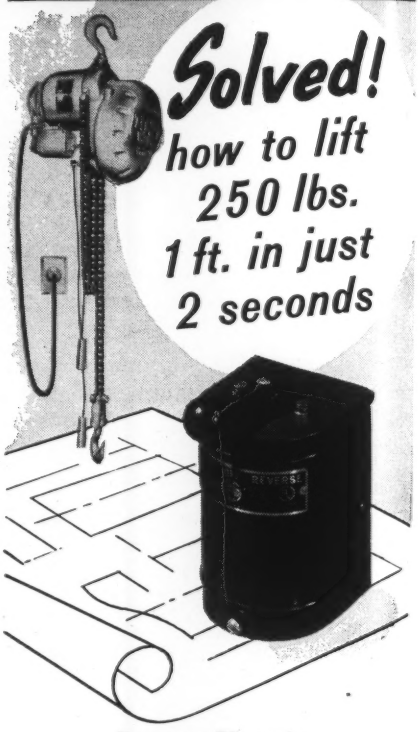
Design Abstracts

sign engineer has a certain definite function in mind for a relay to perform and knows the conditions under which this performance will take place. From this knowledge of functions and conditions, it is possible to express the relay requirements in terms of type and value of voltage or current for contacts to operate and release; time to operate and release; life; temperature limits; enclosure and dimensions; vibration and shock; exposure and the like.

Most manufacturers have certain basic lines of relays designed to meet and anticipate current and future demands. Still, with the exception of certain AN type relays or specified shelf items, most relays are built out of standardized parts and adjusted to a customer's general requirements. The possible range of selection is usually published in a catalog stating what can be expected from the relay in terms similar to those requirements determined by the design engineer. It is only much later, and at an inopportune time usually, that the engineer learns by experience that even such a common and elementary term as "operate current" is not entirely clear and unequivocal. It may be found that the relays supplied malfunction in a particular circuit. The designer may find that he can apply some value of current at which the normally closed contacts, as well as the normally open contacts are open, while the operation of the equipment requires one or the other circuit to be closed. When this anomaly is referred to the relay manufacturer, the designer is usually asked whether the current was applied all at once or gradually, revealing another hitherto unsuspected ambiguity. If the relay is to be employed in a circuit where current may be either steady or variable and if at this juncture the relay manufacturer is not sure whether he can adjust his relay to meet all these requirements, a difficult problem arises.

Life and Reliability: Life of operation is also an important consideration and every relay manufacturer lists the number of oper-

FURNAS ELECTRIC DRUM CONTROLLERS



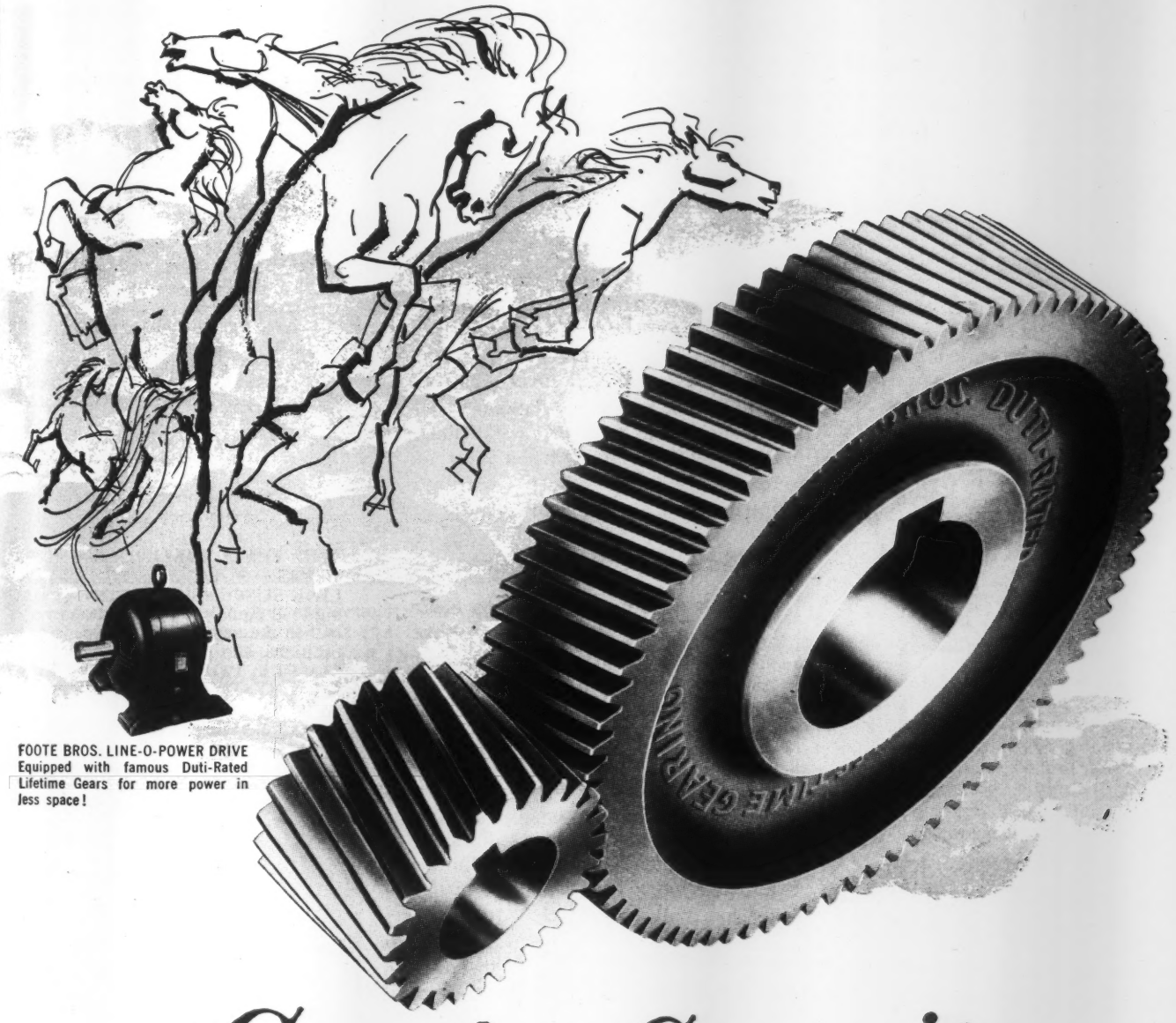
Furnas Electric
DRUM CONTROLLERS
Exclusive on
BUDGIT HOISTS
FOR 14 YEARS

THE REVERSING DRUM CONTROL YOU SEE HERE was designed by Furnas Electric for the Shaw-Box Crane and Hoist Division of Manning, Maxwell & Moore, Inc., of Muskegon, Mich. After 14 years of service on muscle-saving *Budgit* hoists, the smooth responsiveness and durability of this switch is proved beyond question. Finger-tip control allows one hand to control the load while the other guides it. The controller is a modification of standard design.

You'll find a Furnas Electric controller and starter designed to fit your particular requirements. Control types include multi-speed, magnetic or cam. Ratings 1-10 hp, 110 to 550 volts. And you can select from the widest range of magnetic starters in the 1-50 hp range on the market today. In-between sizes save you money and space.

For more facts or Bulletin 48B describing drum controllers, get in touch with your nearby Furnas Electric representative. Or write Furnas Electric Company, 1045 McKee Street, Batavia, Ill.

FURNAS ELECTRIC
Batavia, Illinois



FOOTE BROS. LINE-O-POWER DRIVE
Equipped with famous Duti-Rated Lifetime Gears for more power in less space!

Greater Capacity

COMES IN A SMALLER PACKAGE

FOOTE BROS. Duti-Rated LIFETIME GEARING

FOOTE BROS.

Better Power Transmission Through Better Gears

Manufacturers of industrial gears and enclosed gear drives of all kinds, gear motors, aircraft-quality gears and actuators and special machinery

WITH FOOTE BROS.

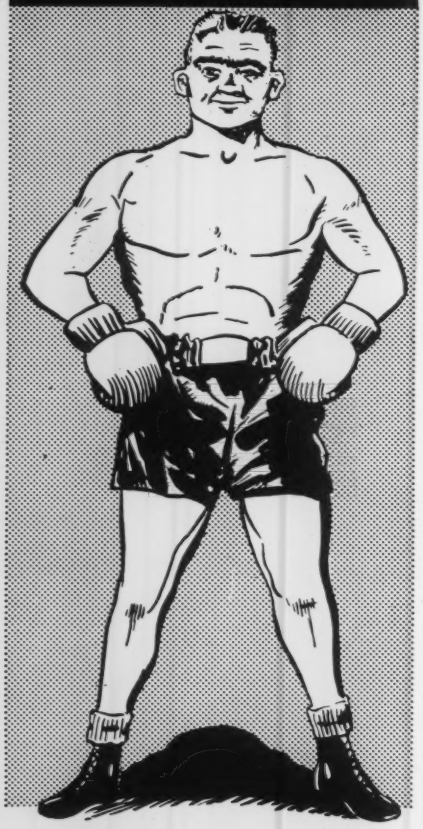
Duti-Rated LIFETIME GEARING

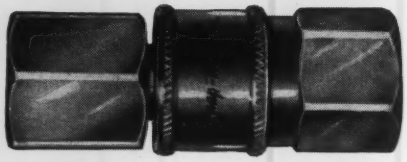
A unique development in industrial gear production... new, *Duti-Rated Lifetime Gears*... a Foote Bros. exclusive! From its vast experience as a leader in aircraft-quality gear manufacture, Foote Bros. has applied the important characteristics of aircraft gearing to its *industrial* gear production. The results are highest quality gears with greatly reduced mass, longer life and higher capacity than ordinary industrial gears. What's more, Duti-Rated Lifetime Gears can *actually cost less* than other gears of similar capacity! The time to investigate is *now* . . . the gears to specify are *Duti-Rated Lifetime Gears!*

WRITE FOR COMPLETE DETAILS... on how Foote Bros. Duti-Rated Gears can fit into your picture. Write *today* . . . for better power transmission *tomorrow!*

FOOTE BROS. GEAR AND MACHINE CORPORATION • 4545 SOUTH WESTERN BOULEVARD • DEPT. O • CHICAGO 9, ILLINOIS

ALL COMERS!





HERE'S THE CHAMP...

YOU SUPPLY THE CHALLENGER

The difficult fluid, gas, or air transmission problem in your plant—We'll send you a Snap-Tite Hi-Flow quick connect disconnect coupling—double or single shut-off or straight-thru—any size 1/8" to 3"—Test it! in your Plant, under actual working conditions—You be the judge—If it doesn't do a better job than the coupling you're now using—Or solve your problem—Ship it back collect! Fair enough? Write today on your letterhead, briefly outlining your problem—We'll ship immediately.

Snap-tite INC.

201 S. WOOD UNION CITY, PENNA.

Design Abstracts

ations under specified conditions of load and usually gives the frequency of operation. However, it is seldom clearly stated what constitutes the end of life except in the undebatable cases where the coil burns out, the armature falls off, or the contacts no longer make or are welded shut. Yet, there are many applications where a two to one rise in contact resistance may endanger the operation of a circuit. Again while specific values of G are usually listed for shock and vibration conditions, there is often little agreement as to what exactly is to be tolerated for contact opening or closing.

Selecting Electric Relays

What then can be done to clear away some of the confusion that attends the selection of the proper relay to perform a given function? First and foremost is the establishment of an adequate set of relay standards and a test code for relays. If a single set of relay standards and a definite and precise method of testing is established, the equipment designer's problem and the work entailed in relay selection will be greatly alleviated. He will be able to evaluate and equate the results of the standard tests performed by the relay supplier with those conditions to which the relay will be subjected in the required application in service. It is rather infrequent that a relay during its life duplicates the same conditions as its "life test" which of course is designed to accelerate and compress its life cycle.

Where the test procedures are clearly outlined, the specific values required for satisfactory operation can also be clearly specified by the designer with little likelihood of confusion or misunderstanding. He will then be free to select the relay by specifying that it must perform a certain function under stated conditions. In listing the performance ratings, he will usually not specify those noncommittant factors such as contact pressure, contact gap or shim tests which contribute to the life or voltage rating of the contacts, leaving this degree of freedom to

DOWNRIGHT DEPENDABLE

VARIABLE-SPEED CONTROL

THE LEWELLEN DOUBLE-BLOCK, UNITIP BELT—keeps tension at a minimum on belt, bearings, and shafts. Contoured lateral blocks are bolted and riveted to an impregnated, plied belt body at closely spaced intervals. Lightweight splice plates are pinned, riveted, and cemented to belt ends. Pin heads interlock with mating splice plates to form a strong, compact splice. Assembled belt is machined and single tips are cemented and pinned to block ends. Here is what it takes in a belt to give dependable performance under all load conditions.

AND THESE DISTINCTIVE FEATURES—FLEXIBLE LEVER & LINK SUSPENSION . . . thrust bearing load equally distributed on every ball in the bearing, at all speeds and positions, and while changing speeds. SIMPLE, POSITIVE LUBRICATION SYSTEM for disc hubs, keys, and shaft.

if it's variable-speed control . . . look to

LEWELLEN

TRANSMISSIONS • MOTOR PULLEYS

Open or enclosed, vertical or horizontal Variable-Speed Transmissions in all sizes from fractional h.p. to 60 h.p.... Variable-Speed Motor Pulleys in all ratings from fractional to 7½ h.p. Speed range, 3 to 1 for all pulley sizes. (One size—2¾ to 1.)

Service in variable-speed control exclusively for more than 50 years. May we help you?

LEWELLEN MANUFACTURING CO.
COLUMBUS, INDIANA

NOWHERE ELSE CAN PRODUCT DEVELOPMENT MEN COMPARE BASIC MATERIALS SIDE BY SIDE

More than 8,000 product development men from all branches of industry attended the 1st Basic Materials Exposition held in New York, last June. Enthusiasm for the exhibits and the ideas presented ran high.

2nd Basic Materials Exposition Offers Product Engineers Only Opportunity To Examine All Materials In One Place

Now product development men have an exposition all their own—the Basic Materials Exposition to be held in Chicago, May 17-20, 1954 at the International Amphitheatre. This new concept in expositions hits at the heart of the problems of the research and development engineer, and the marketing and merchandising executive.

It presents all the available materials and basic product components in one place for easy, side-by-side comparison.

HOW BASIC IS BASIC?

In clarifying the meaning of the Exposition to research and development people, Clapp & Poliak, Inc., producers of the Exposition, said, "We define *basic materials* as the *things* from which *things* are made. They include metals and alloys; plastics; non-metallic materials; coatings, finishes; fabricated parts and forms; and basic components."

The Basic Materials Exposition is a scientific showcase for materials only. It excludes the processing and production machines that so often overshadow materials.

WIDE RANGE OF EXHIBITORS

Scores of leading producers of basic materials and basic product components are planning to exhibit. Their products cover the range of materials from textiles to laminated wood; metal alloys to thermoplastics; metal forms to ceramics and glass, to name a few. Great interest is being taken by government agencies who view the Exposition as an opportunity to broaden the range of materials being used in various defense projects and in atomic energy installations.

Survey Shows 77% Of Engineers Found "Something New"

Seventy seven percent of the engineers in attendance at the 1st Basic Materials Exposition found something new, *not previously used* in their company's products which they will now consider or use; and found *new applications* for materials now being used, an independent survey on attendance reaction revealed.

Twenty nine percent* said they had discovered new uses for materials formerly rejected.

These discoveries show that the design and materials engineers who attended the 1st Basic Materials Exposition *found what they were looking for*. And, it can be expected that attendance at the Basic Materials Exposition in Chicago this Spring will be equally rewarding.

*Totals more than 100% because respondents answered more than one question.

MAIL COUPON TO:
CLAPP & POLIAK, INC.
Show Management E-4
341 Madison Avenue,
New York 17, N. Y.

BASIC MATERIALS CONFERENCE PROMISES RESEARCH AND DEVELOPMENT GUIDANCE

Concurrent with the Basic Materials Exposition will be the 2nd Basic Materials Conference. Headed by T. C. Dumond, editor of Materials and Methods, this year's conference will be patterned around the most asked-for subjects at the past conference. These subjects cover a wide range of materials and materials applications. While the names of panel speakers have not yet been released, the following tentative program is an excellent indication of the worthwhileness of this conference to you and your company.

Monday, May 17

a.m. Review of New Materials Developments.

a.m. Rockets and Guided Missiles— How New Materials for Them will Benefit Industry.

p.m. Erosion and Corrosion —How to Combat Them

Tuesday, May 18

a.m. The New Metal Forming Processes—How, When, and Where to Use Them—
- Shell Molding
- Powder Metallurgy
- Investment Casting
- Impacting
- Extruding

p.m. How, When and Where to Use Nonmetallic Materials
- Plastics
- Carbon and Graphite
- Glass and Ceramics
- Rubber

Wednesday, May 19

a.m. Adhesives and Adhesive Bonding of Metals and Plastics

p.m. How to Set Up and Operate A Materials Department.

International Amphitheatre
Chicago, May 17-20, 1954

BASIC MATERIALS EXPOSITION

The Product Development Show

YES! *I would like to attend the Basic Materials Exposition and Conference.*

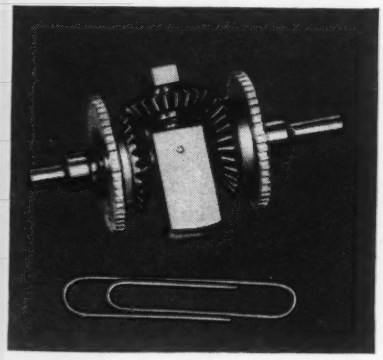
☐ Send me expedited registration tickets for the Exposition. No registration fee.

☐ Send me registration forms for the Materials Conference.

Dept. E-4

Name_____
Title_____
Company_____
Address_____
City_____ Zone____ State_____

the NEW 1/8" MECHANICAL DIFFERENTIAL from FORD INSTRUMENT COMPANY



- Operates in working circle of 1.000" max. diameter
- Lost motion does not exceed 12 mins.
- High sensitivity
- Stainless steel throughout; resistance to wear and corrosion
- Uses Zerol bevel gears.
- Weight, with typical end gears, is less than one ounce

The 1/8" differential is the latest and smallest addition to the Ford Instrument line of single spider gear differentials. Engineered to highest military and commercial standards, this highly reliable unit provides extreme accuracy in additive and subtractive operations, while functioning with minimum friction and backlash.

WRITE FOR FULL DETAILS

Fully illustrated data sheet gives performance curves and characteristics. Please address Dept. MD.

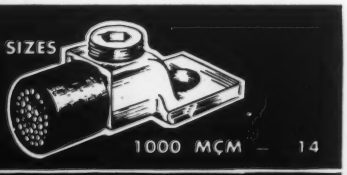
21

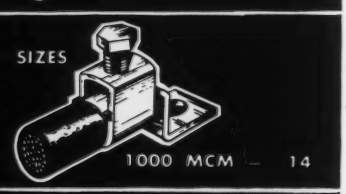
FORD INSTRUMENT COMPANY
31-10 THOMSON AVENUE
LONG ISLAND CITY, N. Y.

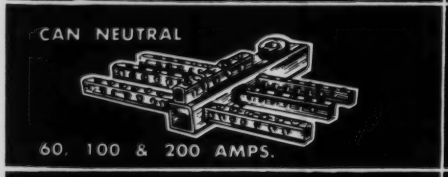
ILSCO

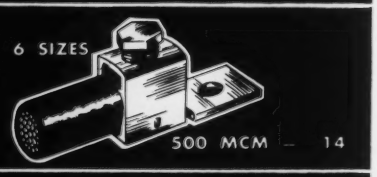
UL QUALITY CSA

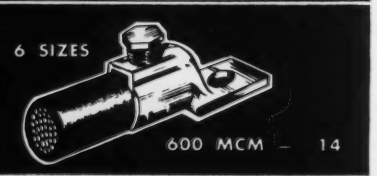
CONNECTORS

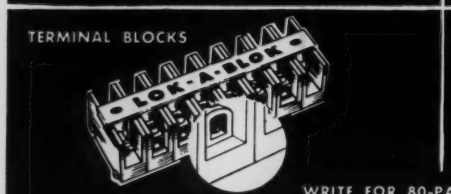


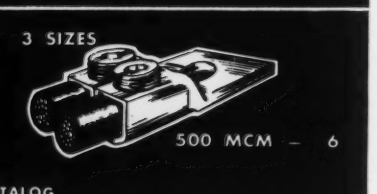












WRITE FOR 80-PAGE CATALOG

ILSCO 5752 MARIEMONT AVE., CINCINNATI 27, OHIO

Design Abstracts

the relay manufacturer to achieve the desired end results.

Space and Weight Requirements: Two other relay requirements which have not been mentioned are the overall physical dimensions and the method of mounting. It is upon these two factors that most standardization programs founder. Of course there are powerful centrifugal forces pulling the relay manufacturers away from standardization. The trend and demand is toward greater miniaturization; greater shock, vibration and temperature requirements; and considerable competitive advantage is gained by developing *the* smallest, *the* etc. In many respects, this is admirable, but it is equally desirable that this proclivity be channelized as much as possible and subjected to some measure of control.

While the program of miniaturization and hermetic sealing has extended the usefulness of relays, it has also greatly contributed to the diversity of shapes and sizes with a corresponding decrease in interchangeability of manufacturer's products. A case in point was where a number of relay manufacturers recently independently produced relays which met the same specification but were not interchangeable because of variations in the mounting dimensions. While no one wishes to stifle the initiative upon which continued progress depends, the establishment and use of certain preferred mounting methods and dimensions can usually be adhered to since few relay design requirements are so rigid as to preclude that possibility.

Practical Objectives: The problems that are inherent in all kinds of relays and their successful solution depends upon the closest cooperation between the equipment designer and the relay manufacturer and the degree to which their respective problems are mutually understood. For if, at all times, the equipment designer thoroughly understands everything he wants the relay to do and is able to adequately specify it in clear terms, and the relay manufacturer knows

ANNOUNCING THE NEW MAXITORQ "DISC-PAC"

A "DO-IT-YOURSELF" UNIT *FOR BUILDING YOUR OWN CLUTCH*

Due to a growing demand for Maxitorq Floating Discs, we now introduce The *MAXITORQ DISC-PAC* . . . a self-contained unit independent of the actuator.

Patented Maxitorq Separator Springs that prevent drag, abrasion, and consequent heating in neutral . . . and the Maxitorq Locking Plate which locks all discs onto body . . . give you the outstanding features that are so highly favored by machine and product designers.

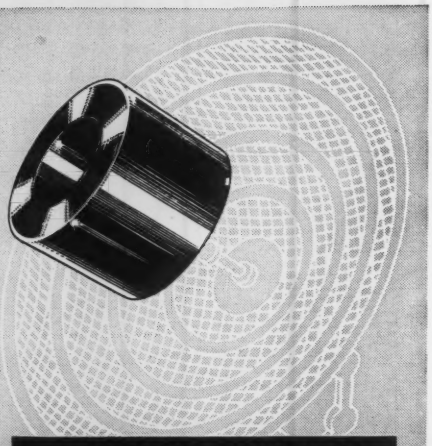
Thus you may build your own clutch or brake from our standard stock Maxitorq parts. The Disc-Pac keys to your shaft and is easily replaced. Units are available in 8-disc diameters from 2″ to 8″; ¼ to 15 h.p. at 100 r.p.m. . . . with 3 lugs on the smallest size, 8 lugs on the 3 h.p., and 12 lugs on the 5, 10 and 15 h.p. capacities.

The Disc-Pac fits Maxitorq standard Driving Rings in the event that you want to use them. As with the Maxitorq Clutch, all assembly, take-apart and adjustments are manual . . . no tools required.

Write Dept. MD-4 for full specifications and quotations.

CJ54

THE CARLYLE JOHNSON MACHINE COMPANY
MANCHESTER • CONNECTICUT



ARE YOU SEARCHING FOR
HIGH PERFORMANCE BEARINGS?

GRAPHALLOY

OIL-FREE
SELF-LUBRICATING
BUSHINGS

Work Where Others Won't!

EXCELLENT DURABILITY • CONSTANT COEFFICIENT OF FRICTION • APPLICABLE OVER A WIDE TEMPERATURE RANGE — EVEN WHERE OIL SOLIDIFIES OR CARBONIZES **• OPERATE DRY, OR AT HIGH SPEEDS SUBMERGED IN WATER, GASOLINE OR OTHER LIQUIDS • EXCELLENT FOR CURRENT-CARRYING BEARINGS**

GRAPHALLOY materials are also in wide use for oil-free, self-lubricating piston rings, seal rings, thrust washers, friction discs, pump vanes, etc.

Other Graphalloy Products

For applications requiring low electrical noise, low and constant drop, high current density and minimum wear. Used for SELSYNS, DYNAMOTORS, SYNCHROS, ROTATING STRAIN GAGE pick-ups and many other applications. Brush Holders and Coin Silver Slip Rings also available.

BRUSHES

CONTACTS

GRAPHITE METALLIZING CORPORATION

1045 Nepperhan Ave. • YONKERS, NEW YORK

☐ Please send data on Graphalloy Oil-Free BUSHINGS.
☐ Send data on BRUSHES and CONTACTS.

NAME & TITLE
COMPANY
STREET
CITY ZONE STATE

Design Abstracts

just as completely what the relay he manufactures will and will not do, a great stride will have been made in the effective and reliable use of relays.

From a paper entitled "The Equipment Manufacturer's Problem Concerning Relay Selection" presented at a symposium on electromagnetic relays at Oklahoma A & M College, Stillwater, Okla., June, 1953.

Minimizing Fretting Corrosion

By E. M. Johnson

Texas Co.
Beacon Laboratories
Beacon, N. Y.

Although there is no panacea for fretting corrosion known to date, there are a number of practices which can be followed to minimize its harmful effects. Since considerable misunderstanding arises at times due to the interchangeable use of the terms fretting, fretting corrosion, friction oxidation and false brinelling to describe the same phenomenon, the following terminology will be used in this discussion:

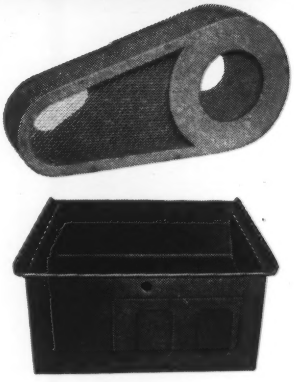
1. Fretting—A form of wear that occurs when two materials are rubbed together with a reciprocating motion of limited amplitude.
2. Fretting Corrosion—A result of fretting which occurs when either one or both of the contacting surfaces are oxidizable.

W. E. Campbell has proposed that fretting corrosion can be subdivided as: (Class 1) Fretting of parts never intended to undergo relative motion, and (Class 2) fretting of parts intended to undergo relative motion some or all of the time. It is to the latter category that this discussion will be devoted. Further, although fretting can be produced between a number of different materials, greatest engineering importance is attached to the fretting corrosion obtained with ferrous metal category.

Effect of Lubricants: If a lu-

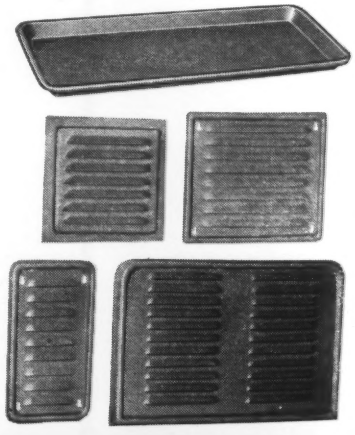
LOUVERS, CHIP PANS, GEAR GUARDS

fabricated to your specifications



For custom-fabrication of sheet-steel or aluminum—you can rely on Industrial to follow specifications, make deliveries on time, and supply carefully fabricated parts for low-cost assembly.

Without obligation, we will quote on your blueprints or supply facts about our complete design service.



Fabrication Division

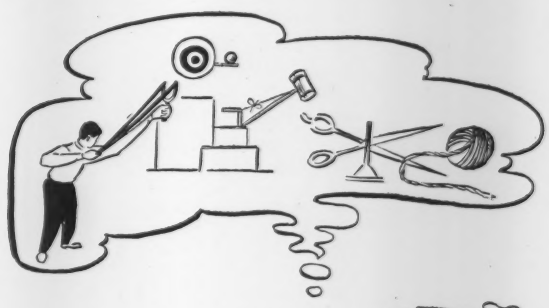
Industrial EQUIPMENT COMPANY

230 Indiana Street
Minster, Ohio

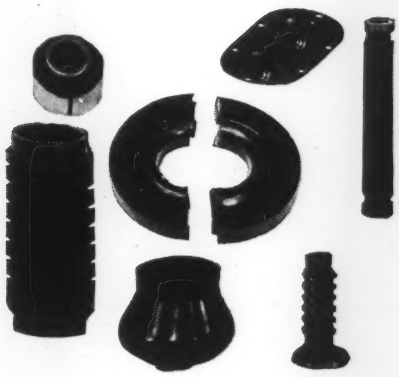
DREAMING OF A WAY TO IMPROVE

YOUR PRODUCT WITH

rubber...



PHOENIX for custom molding



We work in strictest confidence with our customers in development work · Production-integrated laboratory procedures assure high quality control · Skilled craftsmanship maintains closest tolerances · Our time-proved techniques obtain the utmost production from your dies.

Address all inquiries to

RUBBER PRODUCTS DIVISION

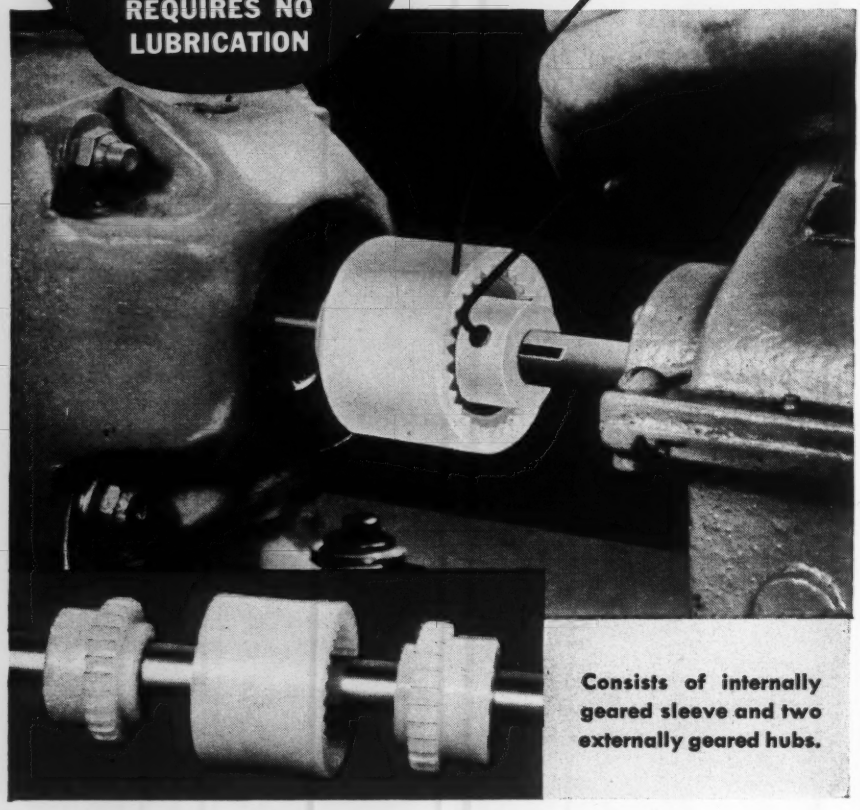
PHOENIX MANUFACTURING COMPANY

JOLIET, ILLINOIS

WALDRON

NON-CORROSIVE
NON-MAGNETIC
REQUIRES NO LUBRICATION

the new nylon
COUPLING



Consists of internally geared sleeve and two externally geared hubs.

weighs 2¼ oz. . . . resists wear

Made of smooth, tough, durable nylon, this new WALDRON "Junior" Coupling provides many operating advantages and economies for smaller fractional H.P. drives.

Non-magnetic and non-corrosive, it is not affected by water, oils, most common chemicals and gases.

Because it requires no lubrication and has nothing to wear out, it is the most economical coupling you can use for longer service without maintenance or repairs.

Available in ⅜"—½"—⅝"—¾" nominal bores.

Write for full particulars, dimension tables, test data, etc.

A product of WALDRON—makers of the famous WALDRON Gear Type and Francke Pin Type Steel Couplings.

JOHN WALDRON CORP.

NEW BRUNSWICK NEW JERSEY

Sales Representatives in Principal Cities

Design Abstracts

bricant becomes excluded from between bearing surfaces for any reason, fretting corrosion proceeds at an increased rate. It has been demonstrated that fretting corrosion can be greatly reduced by the use of low-viscosity fluid lubricants and that submerging bearing surfaces in the lubricant becomes the most important factor in reducing fretting corrosion. This can be achieved in a number of ways including the use of a soft grease, the use of a shear susceptible product and/or the use of a lubricant which will permit bleeding of an oily phase. The following lubricant characteristics must be given careful consideration:

1. Grade (Consistency)
2. Shear Stability
3. Bleeding
4. Composition
5. Additives

Although proper lubrication practices are a primary factor in preventing or reducing fretting corrosion, there are other elements known to influence this important problem.

Hardness and Material: The effect of hardness of bearing parts has not yet been fully clarified. However, the present concept appears to be that the use of surfaces as dissimilar as possible may reduce fretting. In addition, it has been noted that metallizing (spraying a 1.20 per cent carbon steel on a shaft and cold rolling before fitting) is influential in minimizing fretting.

Load: Diversity of opinion exists on this point, with some saying that high load suppresses fretting and others saying that it promotes fretting. It may be that both are correct, depending upon the circumstances. For example, in mating parts where relative motion is not intended, an increase in load may suppress vibration, eliminate slip and prevent fretting. On the other hand in instances where relative motion is intended as occurs in antifriction bearings, an increase in load will increase Hertz deformation which leads to more slip as the bearing

Mr. Charles T. Button, Sales Mgr.
Holtzer-Cabot Motor Division.

"Put our Motor Experience to Work for You!"

"Here at Holtzer-Cabot, we have a superb team of motor specialists who can—and do—solve practically any motor problem that is given them.

"I've been connected with the motor business for nearly 30 years, yet every now and then our design and development engineers will come up with a motor innovation, adaptation or solution that makes me blink!

"Our sales representatives, too, are something to be proud of. They're men of long experience in motor application problems, they have a thorough knowledge of the business, and give customers sound advice and help.

"If *you* have a problem in small-motor applications, take advantage of Holtzer-Cabot's organizational skill and depth of experience. The same engineering ingenuity and manufacturing excellence that have made Holtzer-Cabot the standard of high quality in motors and related electrical apparatus for 78 years are yours to command.

"Write, wire or phone. There is, of course, no obligation on your part by doing so. Your problem will get expert—and prompt—attention."

NATIONAL PNEUMATIC CO., INC. AND **HOLTZER-CABOT** DIVISIONS

125 Amory St., Boston 19, Mass.
PHILADELPHIA • CHICAGO • NEW YORK • CLEVELAND
Sales Service Representatives in Principal Cities throughout the Free World

Designers and manufacturers of mechanical, pneumatic, hydraulic, electric and electronic equipment and systems

YOUR COMPETITOR'S EYE will be quick to see profitable new plastics applications at the National PLASTICS EXPOSITION. New materials, new uses, new equipment—to see and feel. All that's new in plastics at Cleveland, June 7-10. Special conferences, too. Don't *you* miss it. Write for tickets today. On your company letterhead, please. Sorry, not open to general public.

NATIONAL PLASTICS EXPOSITION
sponsored by
THE SOCIETY OF THE PLASTICS INDUSTRY, 67 W. 44TH ST., NEW YORK, N. Y.

Euclid Universal
SPEED REDUCERS

Single reduction worm gear reducers are available in many sizes and ratios.

Euclid Universal 3-way speed reducers are available in a range of sizes from fractional horsepower up to 3 horsepower, depending upon ratio. Some of the noteworthy features, found only in Euclid Universals, are offered as standard:

- *Removable base plate* allows worm shaft to be above or below worm wheel. Output shaft can extend to right or left, be vertical, or have double shaft extension.
- *20° pressure angle worm gears.*
- *Oversize shafts available.*
- *Light weight (aluminum alloy) housings.*

* * *

Write for new Catalog "M-4".

EUCLID UNIVERSAL MACHINE, Inc.

29938 Lakeland Blvd. Wickliffe (Cleveland), Ohio

components pass through the loading area. In this latter case greater fretting would be expected. Therefore, it appears that relative to this factor, each circumstance should be examined independently with respect to the mechanism and operating conditions employed.

Surface Finish and Fit: Confusion also exists on this point, since both smooth and rough finishes are claimed to minimize fretting. However, the majority of evidence appears to be in favor of the rough surface, produced by such treatments as vapor blasting or anodizing. It has been postulated that the rough surface provides innumerable tiny reservoirs for the lubricant, from where it finds easy access to the rubbing surfaces.

Clearance of Fits

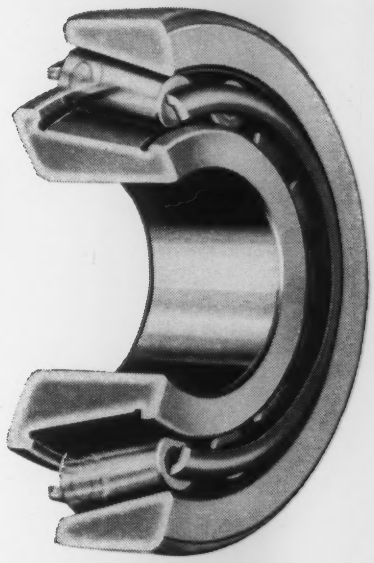
Concerning fits, something may be said for both close fits and loose fits. If clearance is decreased to the point where the lubricant is excluded from mating parts and relative motion continues, a greater clearance would be expected to provide some improvement in fretting relief. Conversely, in needle bearings it is known that the use of tighter fits eliminates jiggling and skewing of needles thereby decreasing fretting. In the case of antifriction bearings, it seems that fits as small as practical to prevent unnecessary motion and yet assure satisfactory operation would be most desirable.

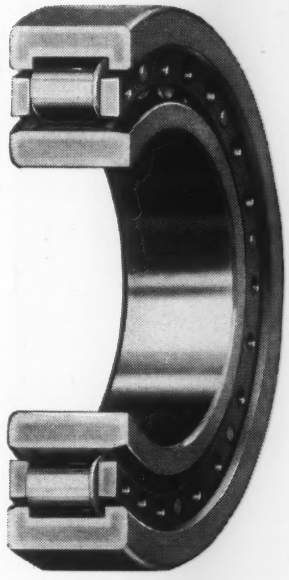
Vibration or Oscillation: Generally, wear tends to increase as amplitude of vibration or oscillation increases. For antifriction bearings, however, this is only true to a point where fresh lubricant can be drawn in by the rolling members. In this manner, dams of fretted debris are broken down allowing ingress of fresh lubricant where needed.

Temperature: Apparently, high surface temperatures are not a prerequisite of fretting, as glass-on-steel fretting may quickly be obtained under very slow trans-

WHATEVER YOUR ROLLER BEARING APPLICATION

specify BOWER!





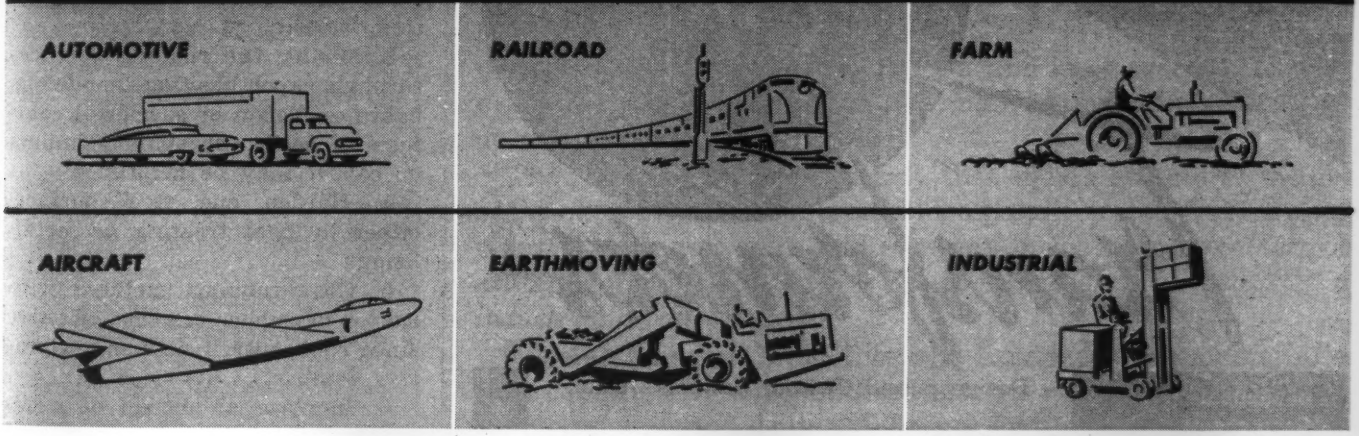
Earthmovers, jet turbine engines, rolling mill equipment, truck axles—you name it! Bower builds a complete line of tapered, straight and journal roller bearings including a size and type to fit *your* product. What's more, these dependable bearings have *proved* themselves in virtually every conceivable type of application. Their built-in quality, skillful engineering and advanced design features provide such important bearing advantages as reduced wear, longer life and lower maintenance requirements. Let a Bower engineer give you full details on the complete Bower line.

BOWER ROLLER BEARING COMPANY
DETROIT 14, MICHIGAN

BOWER TAPERED ROLLER BEARINGS INCORPORATE ADVANCED SPHER-O-HONED DESIGN! Spherically generated roll heads and higher flange with larger, two-zone contact area reduce wear, improve roller alignment and virtually eliminate "end play." This helps hold adjustment and pre-load longer and better. Larger oil groove provides positive lubrication.

BOWER STRAIGHT ROLLER BEARINGS ARE BUILT TO CARRY MAXIMUM LOADS! Integral two-lip race increases rigidity—keeps rollers in proper alignment at all times. Steel cage allows free movement of rollers between races during normal operation. High-grade alloy-steel rollers and races are precision-ground for quieter, smoother operation.

A COMPLETE LINE OF TAPERED, STRAIGHT AND JOURNAL ROLLER BEARINGS
for every field of transportation and industry

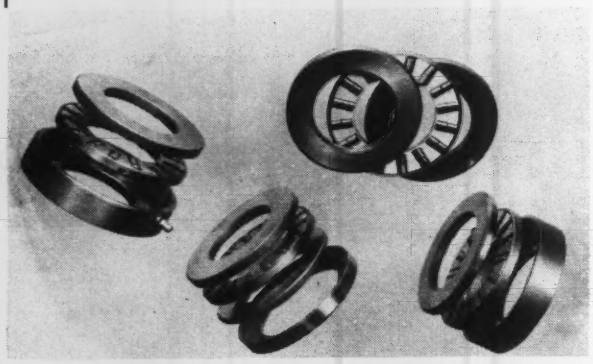


BOWER

SPHER-O-HONED

ROLLER BEARINGS

A COMPLETE SERIES



ROLLER
THRUST
BEARINGS

FLAT SEAT, SELF-ALIGNING, AND CRANE HOOK ROLLER THRUST BEARINGS

Our new catalog #54 gives dimensions and load ratings computed according to the latest AFBMA formulas.

Let us help you select the best bearing for your application. Special bearings are given special attention. Design suggestions will be given at your request.

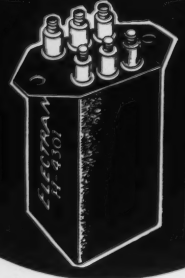
MORTON BEARING COMPANY

815 Wildt Street
ANN ARBOR,

P. O. Box #355
MICHIGAN

ELECTRAN

★ Transformers
★ Saturable Reactors
★ Electronic Devices



Transformers

Dependable Components

Dependable delivery schedules

Designers and Custom Builders—small and medium quantities—from milliwatts to 50 KVA, single or polyphase.

May We Bid On Your Requirements?

ELECTRAN MFG. CO.

1901 CLYBOURN AVENUE • CHICAGO 14, ILLINOIS

verse motion (0.002-inch per second) where the occurrence of hot spots is unlikely. However, there is even some dissension on this point with some postulating that sufficient thermal energy is released to produce local spots of relatively high temperatures during the fretting process.

Humidity: Recently published information from England reveals that humidity can have a marked effect upon fretting with the fretting increasing in severity as the humidity is reduced below 50 per cent for chromium and steel rubbing on steel.

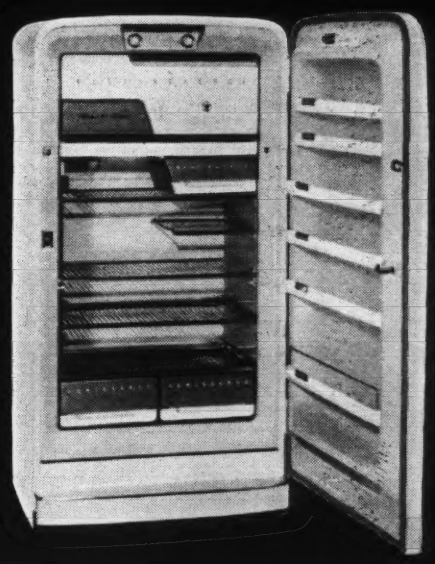
Design Approach

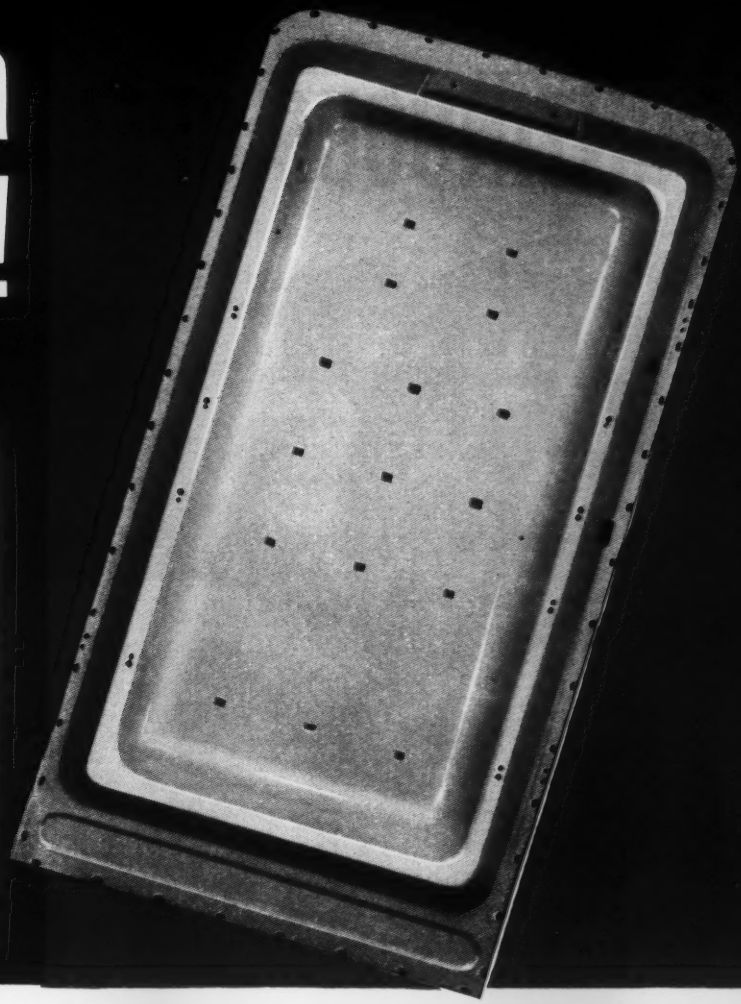
In actual design due to the number of factors entering the problem, it should be apparent that each individual instance requires the determination of the applicable variables and environment before a solution can be obtained. Although some cases may dictate the redesign of portions of equipment, others may permit alleviation or a complete cure by the adoption of those of the following suggestions which are pertinent:

1. Submerge or flood bearing with lubricant of maximum feedability.
2. Relubricate bearing frequently to flush out accumulated fretting debris.
3. Modify the rubbing surfaces through vapor blasting, anodizing, baked-on Teflon or sacrificial coatings of leads, chromium, indium or copper may be helpful.
4. Harden one steel surface, either by heat treating or metallizing.
5. Coat rubbing surfaces with rubber or rubber cement (effective since rubber itself acts as a vibration damper).
6. Increase amplitude of oscillation of antifriction bearings until the ingress of fresh lubricant to rubbing areas is obtained.

From a paper entitled "The Effect of Lubrication of Fretting Corrosion" presented at the SAE Annual Meeting in Detroit, Mich., January, 1954.

Largest area molded!





General American's 1800 square inch inner door panel for the new 1953 WESTINGHOUSE 12FT. REFRIGERATOR

NEW SALES FEATURES:

Not very long ago, engineers would have said, "You can't do it! Too big! Too difficult!" But as in so many cases with plastics, none of the objections held up. Good creative engineering, thorough understanding of materials and large production equipment enabled General American and Westinghouse engineers to do the job.

The result: A panel so sturdy that it is a structural member of the door. Rounded contours which permit flexible shelf arrangement. Many new sales and production features—*another good example of precision molding by General American to back up industry's production lines.*

General American's facilities and experience in molding injection, compression and reinforced plastics may hold the answer to your production needs, too. Why not find out?

Member, Committee on Large Plastics Molding

plastics division
GENERAL AMERICAN TRANSPORTATION CORPORATION
135 South La Salle Street, Chicago 90, Illinois
380 Madison Ave., New York 17, New York

CONTINUOUS OPERATION at any speed

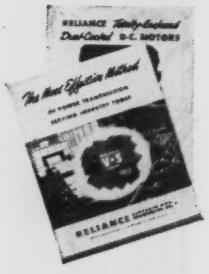
RELIANCE V★S DRIVE ® with

the new *Totally-Enclosed Dual-Cooled* motor

PATENT APPLIED FOR

For continuous operation over extremely wide speed ranges . . . or wherever unusually severe operating conditions must be met . . . the new Reliance Totally-Enclosed Dual-Cooled Motor extends the application range of the V★S Drive. Wherever high ambient temperatures, intermittent operation, prolonged low-speed operation, or severe duty cycles pose difficult cooling problems, Reliance V★S Drive with Dual-Cooled Motors have proved to be the best answer. The new Dual-Cooled Motor is available either totally-enclosed or explosion-proof, conforming to Bureau of Mines and Underwriters' specifications, in ratings from 15 through 150 hp. D-1464-C

Now thru 200 hp.



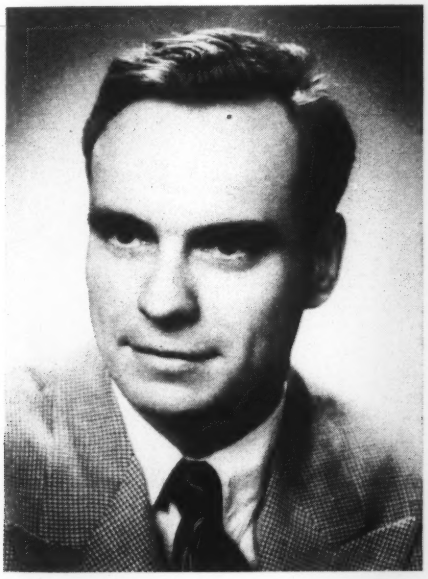
Your request for Bulletin C-2201 will bring you this new booklet featuring large cutaway drawing with 3-color transparent overlay showing operation of Reliance Dual-Cooled Motor, together with fact-filled bulletin showing production increases and operating economies obtainable with Reliance V★S Drive.

RELIANCE ELECTRIC AND ENGINEERING CO.

1079 Ivanhoe Road, Cleveland 10, Ohio • Sales Representatives in Principal Cities

MEN
OF MACHINES

Laurence D. Shergalis joined the staff of MACHINE DESIGN as Assistant Editor on February 22. "Over the Board," page 4 of this issue, contains a discussion of Mr. Shergalis' background.



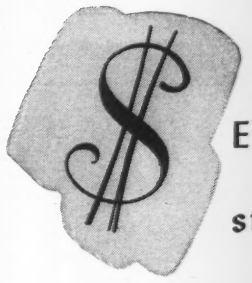
Laurence D. Shergalis

Appointment of **Francis H. Gerlach** as manager of engineering has been announced by Lamb Electric Co., Kent, O. For 11 years Mr. Gerlach was associated with Westinghouse Electric Corp. in the small motor division and for five years was chief engineer of Fasco Industries Inc.

Associated with Ajax Flexible Coupling Co. Inc., Westfield, N. Y., for seven years, **Thomas H. Brumagin** was recently appointed chief engineer.

Greer Hydraulics Inc., Brooklyn, N. Y., has named **James G. Duffy** as group engineer in the research and development center. Before joining Greer in 1951, Mr. Duffy was associated with Sperry Gyro-

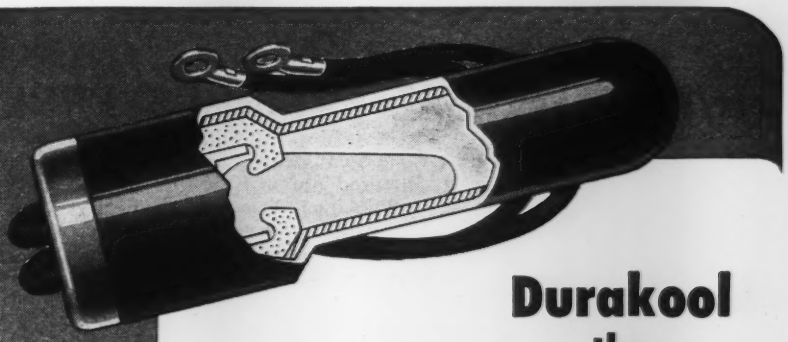
(*Continued on Page* 360)



Everybody knows this sign stands for money ...and smart gear buyers know this sign CINTI stands for the best in custom gears.

CINTI "Gears... Good Gears Only"

THE CINCINNATI GEAR CO. • CINCINNATI 27, OHIO



Durakool the STANDARD OF QUALITY, DURABILITY AND LIFE

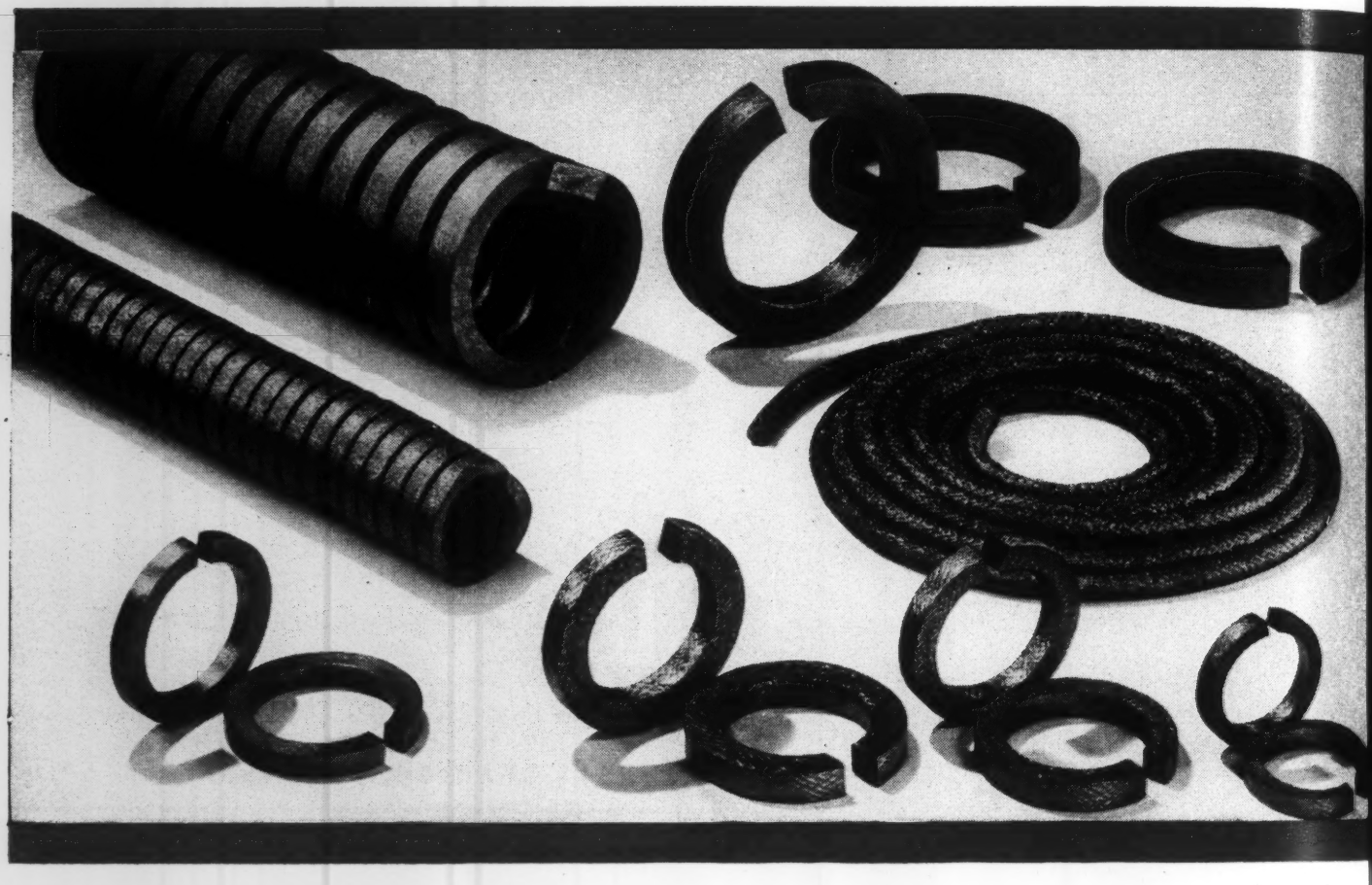
WITHSTANDS HIGH TEMPERATURES

Years of trouble-free performance on the most difficult of assignments have won top recognition for Durakool Mercury Tilt Switches. High temperatures, fast cycling and 24 hour schedules taken in stride. 7 sizes, 1 to 65 amperes. Send for Bulletin 525.

See telephone directory for local distributor or write
DURAKOOL, INC. — Elkhart, Indiana

Durakool ALL-STEEL MERCURY Switches

CALL ON R/M ENGINEERING SERVICE



R/M UNIVERSAL PACKINGS PROLONG EQUIPMENT LIFE

A pump or a valve stem is only as good as the packing in it. Pictured above is R/M's line of Universal Plastic Packings. They are engineered so precisely to pump and valve requirements that they permit the practice of preventive rather than corrective maintenance. Their lubricants, ground in during manufacture, are so securely locked within the compound that even after wear sets in, the effectiveness of the bearing surface remains unchanged. An unusually uniform dispersion of long asbestos fibers throughout the binder gives them a completely homogeneous construction and, therefore, tremendous stability under pressure. And because no organic materials are included—only the cleanest, softest, most open fibers obtainable—they have exceptionally high resistance to heat.

The complete R/M line includes packings and gasket sheets for use against air, gas, water, steam, oil, chemicals, solvents, food products and hydraulic fluids. R/M also makes a wide variety of "TEFLON"* products and an unusual number of asbestos textiles. If you have problems involving any of these materials or products, feel free to call on R/M's specialized engineering service.

**Du Pont's trade-mark for its tetrafluoroethylene resin*

For booklet shown, or other data, write, phone or wire:

PACKING DIVISION OR
ASBESTOS TEXTILE DIVISION
Raybestos-Manhattan, Inc.
Manheim, Pa.
Manheim 5-2211

R/M

SPECIALISTS IN ASBESTOS, RUBBER, SINTERED METAL, ENGINEERED PLASTICS

Brake Blocks, Linings and Clutch Facings

Fan Belts and Radiator Hose

Mechanical Packings and Gaskets

Abrasive and Diamond Wheels

Industrial Drive Belts

Industrial and Automotive Hose

FOR HELP IN SOLVING YOUR PROBLEMS

SINTERED METAL PARTS

If you have a friction material application that requires close tolerances or an operating condition that calls for immersion in oil, R/M can provide you with sintered metal parts engineered to your specific needs. It can also meet your requirements for woven and molded asbestos or semi-metallic materials. Feel free to call on R/M engineering service for advice on problems which involve any type of friction materials. For practical design and engineering data on R/M woven and molded asbestos friction materials and sintered metal, write for R/M Bulletin No. 500.

For Bulletin No. 500, or other data, write, phone or wire:

EQUIPMENT SALES DIVISION
Raybestos-Manhattan, Inc.
6010 Northwest Highway
Chicago 31, Ill.
ROdney 3-2400

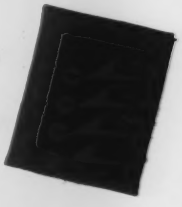
Just off the press!

R/M CONVEYOR BELTS

The amazing new "XDC" Cover gives phenomenal resistance to wear, abrasion, cuts and tears on heavy duty R/M conveyor belts for grueling loads. The same XDC development also puts longer life into lighter service belts for portable and weighing conveyors, table and small parts conveyors, package conveyors, in food belts, flanged and ribbed belts. R/M custom-designs conveyor belts for any required condition, for resistance to heat, acid, oils, etc. If you have a design problem involving industrial rubber products . . . write to the Manhattan Rubber Division.

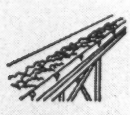
For booklet shown, or other data, write, phone or wire:

MANHATTAN RUBBER DIVISION
Raybestos-Manhattan, Inc.
Passaic, N.J.
GRegory 3-2000

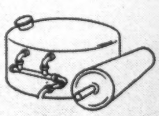


RAYBESTOS-MANHATTAN, INC.

FACTORIES: Passaic, N.J. • Bridgeport, Conn. • Manheim, Pa. • No. Charleston, S.C. • Crawfordsville, Ind. • Neenah, Wis. • Peterborough, Ontario, Canada



Conveyor Belts



Rubber Lined and Covered Equipment

Sintered Metal Friction Elements

Asbestos Textiles

Teflon Tape, Packings, Sheets, Rods, Tubes

Engineered Molded Rubber and Plastics

R/M

O-M CYLINDERS
(air • hydraulic)

FIT WHERE OTHERS WON'T!

O-M Cylinders require up to ⅓ LESS INSTALLATION SPACE than conventional cylinders of the same bore, because O-M's *Special Interlocking Mechanism* eliminates projecting tie rods and bulky end caps. In addition, the "O.D." of O-M Cylinders can be easily and accurately machined for cartridge mounting within your equipment.

O-M Special Interlocking Mechanism also assures perfect alignment giving O-M the lowest coefficient of friction of any cylinder. Thus, O-M Cylinders are smoother operating at low or high speeds regardless of length of stroke. Easily removed, inspected, repaired, replaced. Completely interchangeable parts.

Available in a full range of sizes (1½" to 8" bores) with standard, 2 to 1 or oversize rods.

14 day delivery on most sizes

Write today for FREE catalog and complete set of ½- and ¼-scale templates showing all cylinders and mounting brackets.

MAIL COUPON NOW!

ORTMAN MILLER MACHINE CO.

1210 150th Street • Hammond, Indiana

☐ Please send latest O-M catalog.

☐ Please send complete set of templates.

Name.....

Company.....

Address.....

City.....Zone...State.....

Men of Machines

(*Continued from Page* 357)

scope Corp., with the Fairchild project at Oak Ridge, in the atomic energy division of H. K. Ferguson Co., and with the Walter Kidde Nuclear Laboratories.

Robert C. Leff was recently appointed chief engineer of Sta-Rite Products Inc., Delavan, Wis. He will be responsible for engineering activities in both the domestic water system and the industrial pump fields. Mr. Leff was associated with Marlow Pumps for seven years, the last three years as chief engineer.

Donald H. Rogers

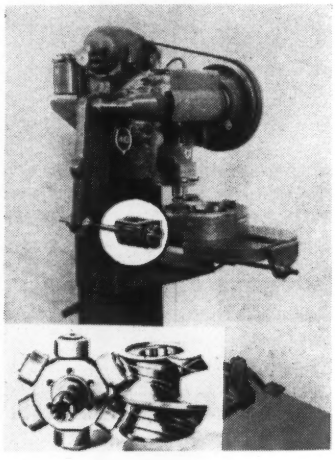
Recently appointed chief engineer of Blonder Tongue Laboratories, Westfield, N. J., **Donald H. Rogers** is responsible for the company's research and development programs. Previously he supervised electronic development work for Western Electric Co. and Utility Electronics Corp. The author of many technical papers, Mr. Rogers prepared the article, "Management of Drafting," which begins on Page 112 of this issue of MACHINE DESIGN.

Cincinnati Milling Machine Co., Cincinnati, recently formed a machine tool division and appointed **Swan E. Bergstrom** manager. Mr. Bergstrom's responsibilities in-

(Advertisement)

High Speed Roller Gear Indexing for Dial Operations

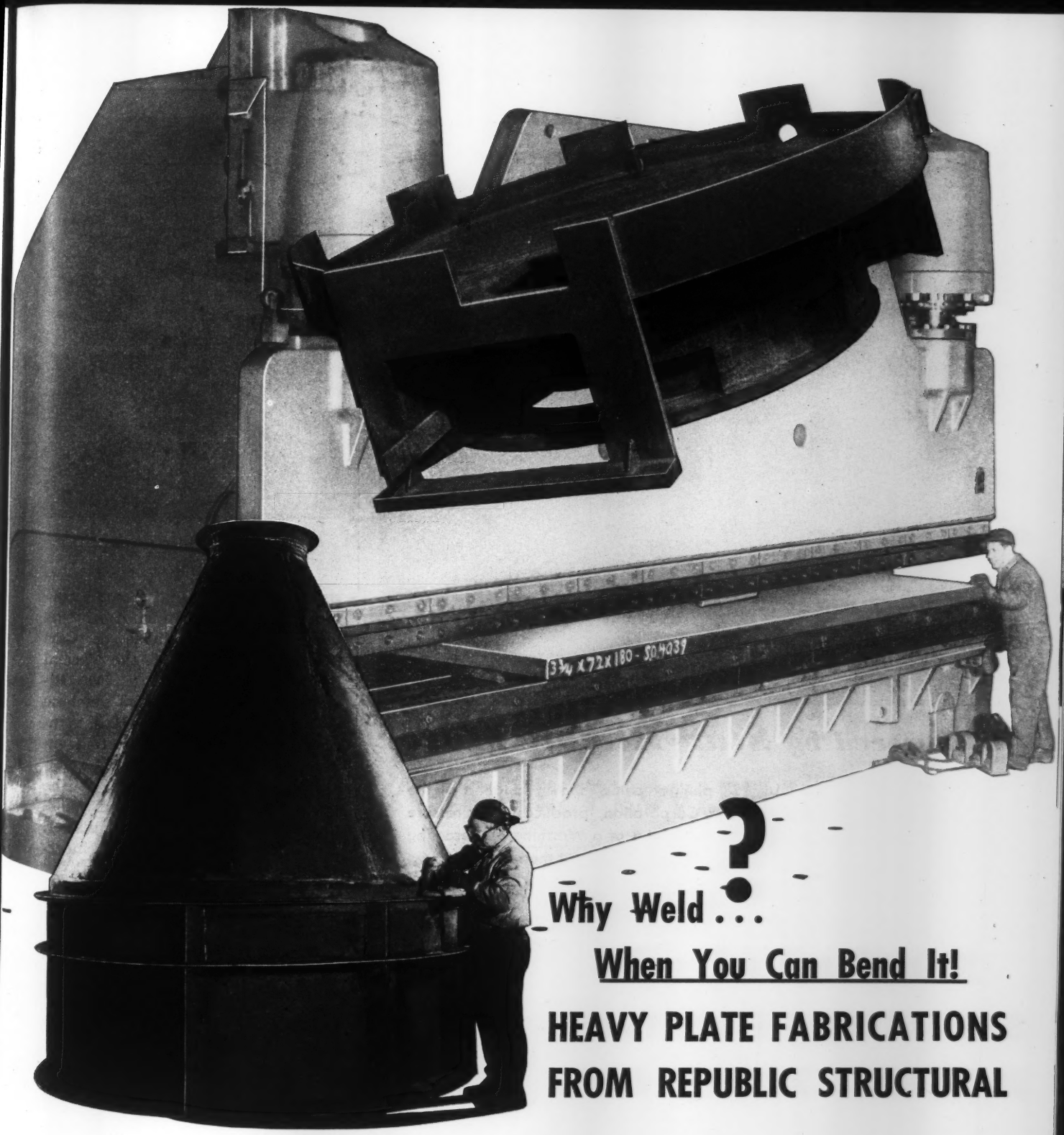
The Ferguson Roller Gear Drive, a new type of indexing mechanism, has been outstandingly successful in increasing the capacity of equipment where rate of production has been limited by the dial indexing speed. The better accelleration characteristics and the inherent versatility of the Drive design often results in speeding up machinery as much as 200% of original capacity while realizing greater precision without auxiliary locating mechanisms —even eliminating the need for secondary sizing operations. The Drive is designed to require no maintenance for at least 8,000 hours of operation and may be renewed merely by replacing the standard ball bearings.



The V & O High Speed Notching Press utilizes a FERGUSON ROLLER GEAR DRIVE (inset) with 6 stops, 270° indexing period at speeds up to 750 indexes per minute.

In addition to the many standard models for new and existing machinery, there are custom-designed units with any number of stops from two to infinity and with indexing periods ranging upwards from 90°. This great design versatility has allowed many successful and varying applications to dial indexing, roll feed and carrier chain indexing, as well as other types of indexing involving either lineal or angular movement. See the Ferguson Roller Gear Drive in operation at Booth No. 505, American Society of Tool Engineers Convention at Philadelphia, April 26-30.

For more information, write to Ferguson Machine & Tool Co., Dept. 85, Box 191, 471 Paul Ave., St. Louis 21, Mo.



Why Weld . . .

When You Can Bend It!

HEAVY PLATE FABRICATIONS FROM REPUBLIC STRUCTURAL

Our 1,000 ton Press Brake is the positive answer to lower cost, higher quality fabrications! Weldments designed with our Press Brake and its possibilities in mind have a smoother, more streamlined appearance. They're often stronger, more resistant to shock and take greater abuse.

Write for our brochure on this Press Brake and our extensive facilities . . . ask our engineers how this Press Brake can help you produce a better designed fabrication at a lower cost!

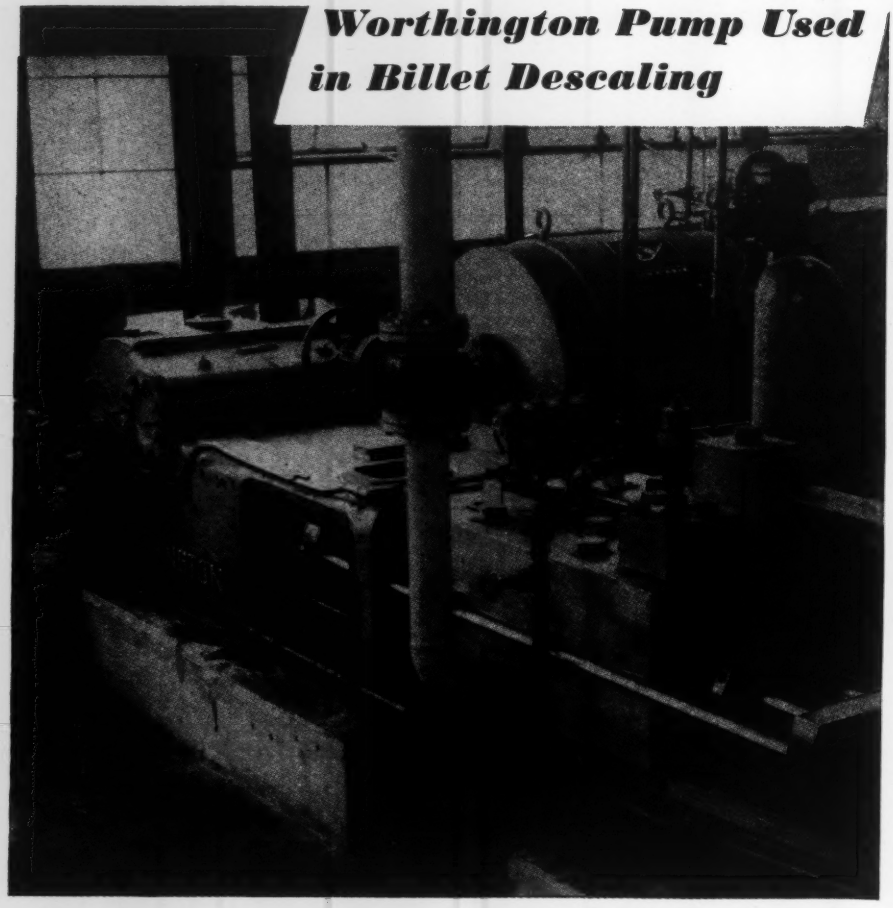
Republic Structural Iron Works

Division of

THE CONSOLIDATED IRON STEEL MFG. CO.

1290 East 53rd St. • [illegible] • [illegible]

Worthington Pump Used in Billet Descaling



is powered by Star-Kimble Motor

This Worthington 2¾" by 12" plunger pump, shown installed at the South Bend Plant of the Oliver Corporation, produces the pressure needed to force water through the nozzles of a Worthington descaling system. Billets are fed into the descaling cabinet at the rate of 125 an hour. To maintain uninterrupted production flow at this rate of descaling calls for an unfailing supply of water to the nozzles of 110 gpm at 2,500 psi. To power the pump for this service, Worthington selected a Star-Kimble squirrel-cage motor.

IN ADDITION

Star-Kimble designs and builds special and standard motors — squirrel-cage, wound rotor and d-c types — to meet specific requirements in all major industrial fields of motor applications, including machine tools, marine, materials handling and processing equipment.

For information on standard squirrel-cage motors, write for Bulletin B-201.

Standard and special motors of all types, 1 to 125 hp; generators and motor-generator sets, 1 to 100 kw; Marine motors ½ to 125 hp.

Star-Kimble
MOTOR DIVISION
of Miehle Printing Press and Mfg. Co.

201 Bloomfield Avenue Bloomfield, New Jersey

Men of Machines

Swan E. Bergstrom

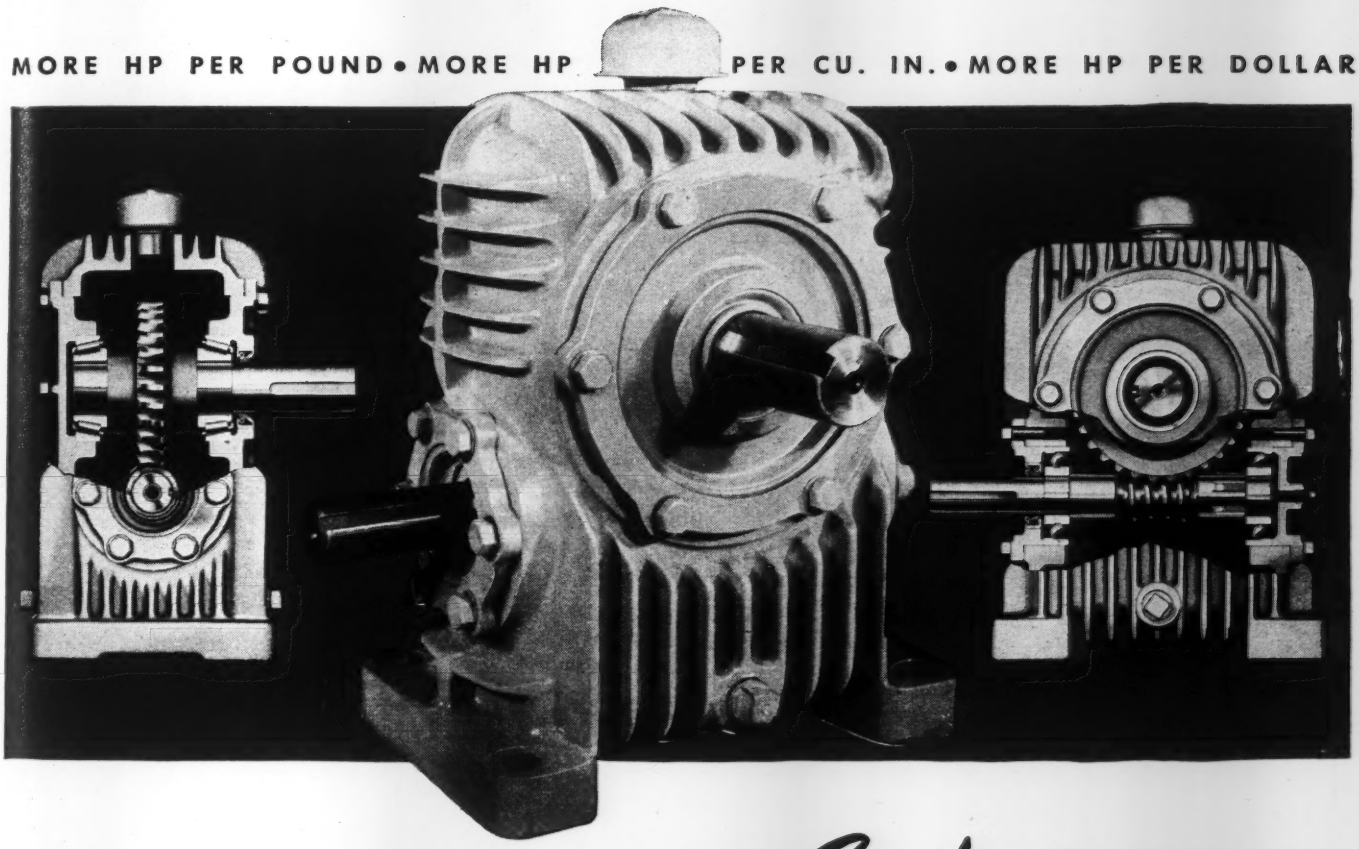
clude engineering and manufacturing. Other appointments in this new division are those of **Carl Stugard,** manager of the special machine tool section; **Ed Rivoira,** manager of special machine tool engineering; and **Al Dall,** manager of standard machine tool engineering and development.

Another major division of the company, the machinery division, now has **E. D. Vancil** as manager. Mr. Vancil was formerly engineering manager of this division.

L. F. Nenninger, former works manager who was to have served as assistant to Mr. Bergstrom in

E. D. Vancil

MORE HP PER POUND • MORE HP PER CU. IN. • MORE HP PER DOLLAR



190,000 STANDARD *Stock* ANSWERS TO *Your* DRIVE PROBLEMS

Look closely at the cutaway views above. Note how the worm wraps around the gear and the gear around the worm. That's the double-enveloping principle of Cone-Drive gears. It gives you high load-carrying capacity, long life and less weight, all in an extremely compact unit.

Size for size, Cone-Drive speed reducers will out-perform any other worm geared speed reducer on the market.

Yet, you can select any one of 190,000 standard stock reducers to solve your specific drive problem the efficient way.

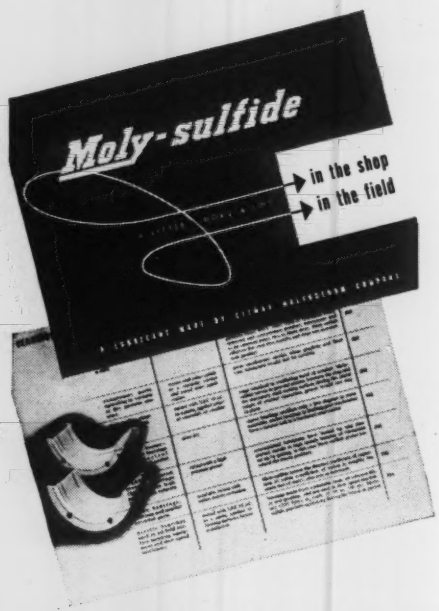
You can choose ratios from 5:1 to 4900:1.
You can handle loads from fractional to 800 hp.
You get all this with only 58 standardized mountings.

Cone-Drive gears offers this versatility because of their modern manufacturing methods. All parts for a given center distance—gears, mountings, bearings, housings, fan-cooling attachments and water cooling coils, etc.—are standardized whether you require worm under or over, gear shaft vertical or horizontal, single or double-extended shafts, right or left hand. All of these parts are completely interchangeable for a given center distance, too.

Find out more about Cone-Drive speed reducers. Ask for Bulletin 8901-50.

CONE-DRIVE GEARS
Division, Michigan Tool Company
DOUBLE ENVELOPING GEAR SETS & SPEED REDUCERS
7171 E. McNichols Road • Detroit 12, Michigan

154 ideas on ways to use...



154 varied applications of molybdenum sulfide in the shop and in the field are described in a new booklet now available. This solid-film lubricant has demonstrated unique anti-friction properties under conditions of extreme pressure, high velocity, elevated temperature, or chemical attack.

The 40-page booklet contains the records of solved lubrication problems — some might solve your own. Fill in the coupon below, attach it to your letterhead and send it off today.

Moly-sulfide
A LITTLE DOES A LOT

The lubricant for extreme conditions

Climax Molybdenum Company
500 Fifth Avenue
New York City 36 N Y

Please send me your Free Booklet on *Moly-sulfide*
Name.....
Position.....
Company.....
Address.....

MOLY

MD-4 MS-6A

Men of Machines

the machine tool division, died March 16.

R. G. Ellis was recently promoted to assistant chief engineer of Micromatic Hone Corp., Detroit. A machine tool designer for 27 years, Mr. Ellis has been associated with the company since 1939.

W. Waits Smith has been named manager and **Allan Chilton** appointed chief engineer of the aviation gas turbine division of Westinghouse Electric Corp. Mr. Smith will be in charge of all phases of jet aircraft engine development at the company's Kansas City, Mo., and South Philadelphia, Pa., plants.

Minnesota Mining & Mfg. Co., St. Paul, Minn., recently appointed **Robert C. Anderson** assistant director of engineering for staff laboratories and **Frank J. Vette** assistant engineer of the adhesives and coatings division.

Walter J. Crotty Jr. has been appointed chief of the mechanical engineering department in the engineering research division of Miller Metal Products Inc., Baltimore. He was previously associated with the Glenn L. Martin Co., Budd Mfg. Co. and Baldwin Locomotive Works.

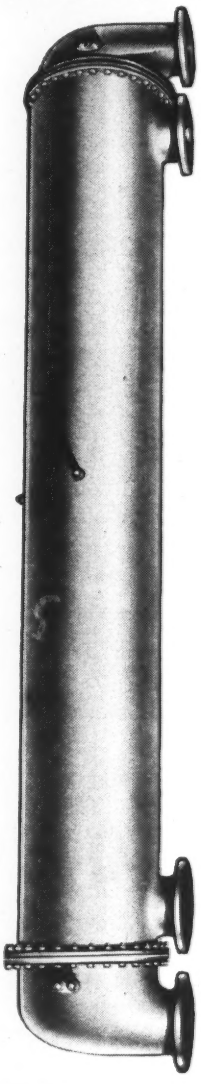
Kenneth J. Downs has been appointed chief design engineer of Chiksan Co., Brea, Calif., to supervise the design and development section of the engineering department, as well as to direct operation of the test laboratory.

W. H. C. Berg has been named director of standards and research for the Hanson-Whitney Div. of Whitney Chain Co., Hartford, Conn.

Prof. Robert S. Green, chairman of the department of welding engineering at Ohio State University,

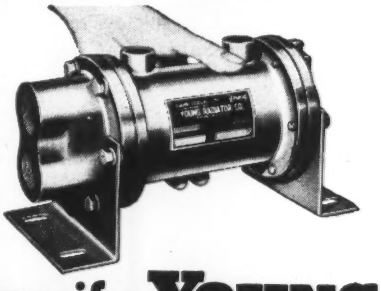
WHETHER YOU NEED

LONG



OR...

SHORT ONES...



Specify YOUNG
Shell and Tube
HEAT EXCHANGERS
690 standard models; lightweight, rugged, compact. Single and multipass, fixed and removable tube bundle. Catalog on request.

Young Radiator Company
Dept. 304-D • Racine, Wisconsin
Plants at Racine, Wis., and Mattoon, Ill.

YOUNG
Heat Transfer Products for Automotive, Industrial, Gas or Diesel Engine Applications.
Heating, Cooling, Air Conditioning Products for Home and Industry.

Leaders in Heat Transfer Engineering for Over 25 Years.

SPLIT DIE FORGING

FOR AMERICAN INDUSTRY

BETTER PRODUCTS

LARGE SIZES*

INTRICATE SHAPES

AT REDUCED MANUFACTURING COSTS

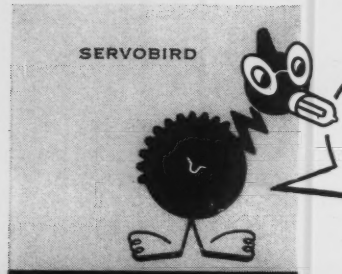
*Large sizes and intricate shapes can now be forged up to 5,000 pounds.

FORGE AND ORDNANCE DIVISION

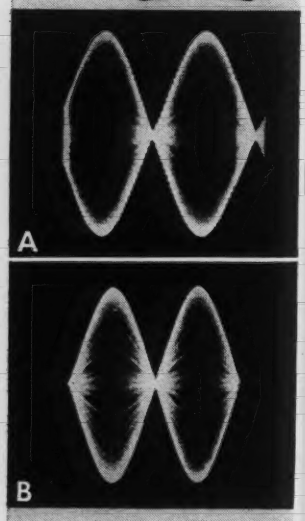
Cameron

IRON WORKS, INC.
HOUSTON, TEXAS

Write for illustrated brochure.



Is Your Servo Nonlinear?
Is the Output of Your
L-F Amplifier Distorted?



THE SERVOSCOPE® is Your Solution

The Servoscope gives you phase and amplitude characteristics even when the wave forms are not sweet and clean sine waves.

The phase dial is rotated until the oscillogram **(A)** becomes symmetrical, as at **(B)**, and presto — you have your answer!

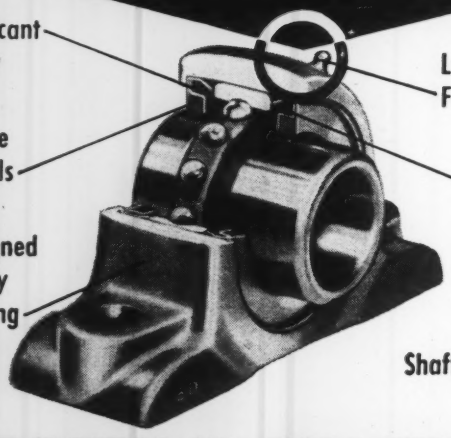
Degree and type of distortion are visible, too.

For detailed information on how this versatile test instrument can save you man-hours, write Dept. MD-4.

SC112

SERVO CORPORATION OF AMERICA
NEW HYDE PARK, NEW YORK

An Ahlberg plus feature in
LOW COST BEARINGS



ED SERIES
(LIGHT DUTY)
Shaft sizes: ½" to 1-3/16"
others to 2 15/16"

LIGHT DUTY BALL BEARING PILLOW BLOCK

For those jobs where cost is the primary factor, it will pay you to investigate the light duty, low cost ball bearing unit. Let us send you bulletin 7149A.

AHLBERG BEARING CO. 3025 W. 47th Street Chicago 32, Ill.

AHLBERG
PRECISION BUILT BALL BEARINGS SINCE 1908

Men of Machines

has been named executive director of the university's Engineering Experiment Station.

S. N. Bean, formerly chief tool engineer of the California division of Lockheed Aircraft Corp., has been promoted to chief manufacturing engineer for the company's Marietta, Ga., division.

Colonial Broach Co., Detroit, has promoted **Glen Harmon,** assistant chief engineer for the last four years, to new engineering duties which include broaching research.

Wallace L. Howe has been elected vice president in charge of research and development and a director of Norton Co., Worcester, Mass.

Edwin Burke was recently appointed project engineer at the Midland, Pa., works of Crucible Steel Co. of America. He was formerly associated with United Engineering & Foundry Co.

Formerly supervisor of automatic controls systems, **Joseph Abdo** has been named chief engineer of all divisions of Drayer-Hanson Inc., Los Angeles.

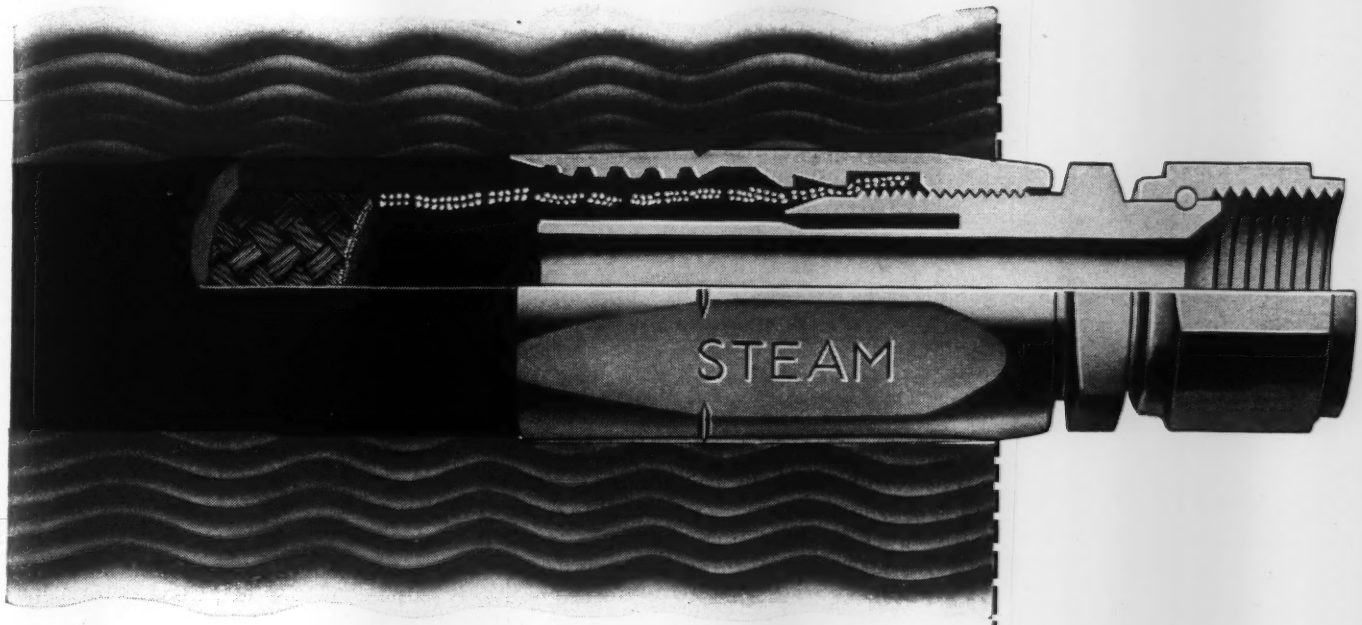
Francis Weiss has been named director of the newly created development department of Alliance Machine Co., Alliance, O. He has been associated with the Steelton plant of Bethlehem Steel Co. for 14 years.

Vice president and chief engineer since 1950, **Russell F. LaBeau** is now executive vice president in charge of all operations of Sutter Products Co., Detroit. **Earl J. Blough** has been named chief engineer.

William W. Fisher has been appointed vice president in charge of operations for American Type Founders Inc., Elizabeth, N. J. He will be responsible for the com-

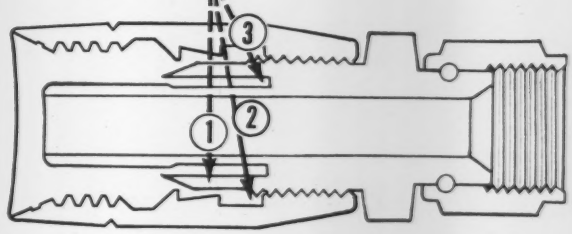
The Steam Hose Line with a FUTURE!

ANOTHER AEROQUIP FIRST!



Now . . . a steam hose line built for extra l-o-n-g life! The secret is in Aeroquip's reusable "*little gem*" fittings that assure positive attachment to the hose and never need re-tightening once assembled. The knife-like spur (1), see diagram, of the "*little gem*" separates the inner tube from the wire braid; clamping action (2) is exerted on reinforcing braid only; and a lip seal (3) is formed by the end of the inner tube in an annular chamber. The "*little gem*" is a streamlined, compact fitting with no bolts or protruding surfaces to hinder handling. In perfect combination with Aeroquip burst-proof steam hose, it offers greater efficiency and maximum safety. *Truly another Aeroquip first in better hose lines!*

Longer Life!



Aeroquip

REG. TRADE MARK

STEAM HOSE MATCHED WITH "*little gem*" FITTINGS

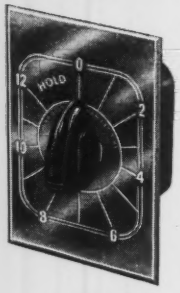
"*little gem*" is an Aeroquip Trade Mark

AEROQUIP CORPORATION, JACKSON, MICHIGAN

SALES OFFICES: Burbank, Calif. • Dayton, Ohio • Hagerstown, Md. • High Point, N. C. • Miami Springs, Fla. • Minneapolis, Minn. • Portland, Ore. • Van Wert, Ohio • Wichita, Kan.
IN CANADA: Prenco Progress and Engineering Corporation Ltd., Toronto • **IN ENGLAND:** Super Oil Seals & Gaskets, Ltd., Birmingham

AEROQUIP PRODUCTS ARE FULLY PROTECTED BY PATENTS IN U.S.A. AND ABROAD

MARK-TIME
"9000" Wall
Time Switch



turns current
off or on WHEN
YOU'RE NOT THERE!

This Mark-Time switch is a good deal more than a great convenience . . . it saves you money! Because it remembers to turn the current off or on when you're not there to do it!

"9000" automatically controls circuits of store window lights, neon signs, hall and garage lights, attic fans, farm lighting systems . . . dependably turning them on or off at the time you set.

"9000" is easily mounted in any standard rectangular wall box. Movements only available for home or industrial heating controls.

Write today for full details and prices.

SPECIFICATIONS

Time ranges from 3 minutes to 12 hours. Rated at 20 ampere, 125 volt, 1 HP or 10 ampere, 250 volt operation. AC only. Available for either ON or OFF type operation. Hold feature also available—at HOLD position, current is ON, but timing mechanism does not operate until knob is turned from HOLD to a time period.

MARK-TIME
M. H. RHODES, INC.
HARTFORD, CONNECTICUT

Manufactured and sold in Canada by
SPERRY GYROSCOPE OTTAWA, Limited
3 Hamilton St., Ottawa, Ontario, Canada

Men of Machines

pany's research program, as well as engineering and manufacturing activities at the Elizabeth plant. Mr. Fisher will also give functional direction to engineering and manufacturing operations at the company's new plant in Mt. Vernon, N. Y.

N. F. Adamson has been elected to the board of directors of the Twin Disc Clutch Co., Racine, Wis. He joined the company in 1925 as a member of the engineering department, served as a sales engineer, was appointed chief engineer, then sales manager, and in 1945 was elected vice president in charge of sales and engineering.

General Motors Research Laboratories, Detroit, has announced that **Lloyd L. Withrow,** head of the fuel and lubricants department, and one of his assistants, **Frederick W. Bowditch,** received the tenth Harry L. Horning Memorial Award from the Society of Automotive Engineers. The award was made for a technical paper, "Flame Photographs of Autoignition Induced by Combustion Chamber Deposits," which Drs. Withrow and Bowditch delivered before the SAE in January 1952.

At a recent meeting of the board of directors, **Edgar G. Seybold** was elected president of the Hendey Machine Co. Inc., Torrington, Conn.

Belgian Electric Sales Corp., New York, has announced the appointment of **Edmond Charles Falleur** to the post of chief technical engineer.

Thomas L. Sherman has been named a consultant at Battelle Institute, Columbus, O. Mr. Sherman, who has done extensive work in the development of high-performance diesel engines, will work with the mechanical engineering division. He formerly served as consulting engineer for the Fairbanks-Morse Co. and was chief engineer of the diesel engine division

Leading The Field In
FLOW REGULATION

Where a constant flow of fluid is automatically required regardless of pressure or back pressure variations you will find the answer in a WATERMAN FLOW REGULATOR. Small and compact in design, taking up little more space than the fluid carrying line itself, WATERMAN FLOW REGULATORS give years of dependable trouble-free service.

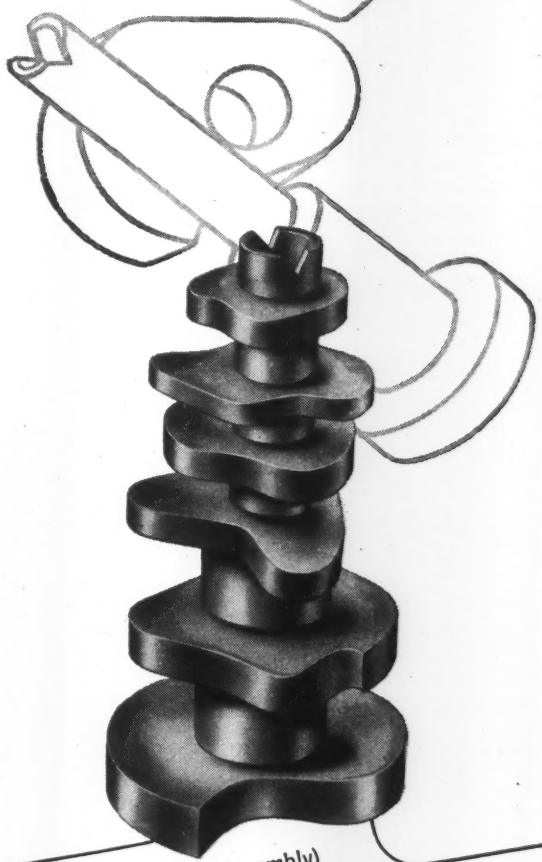
Here is an example of Flow Regulators used as standard equipment by Automatic Transportation Co. in their Skylift trucks. More and more manufacturers incorporating hydraulic equipment in the products they manufacture are finding that WATERMAN FLOW REGULATORS simplify circuits, reduce weight, space, and cost while providing automatic flow regulation.

Available in a range of sizes and a variety of models to take care of your requirements.

Write for our illustrated brochure F

Waterman
ENGINEERING COMPANY
725 CUSTER AVENUE • EVANSTON, ILLINOIS

Miracle ...NO! AN ENGINEERING ACHIEVEMENT



When 7 Parts are Reduced to 1

True it's something of a record when 7 parts are combined to make 1... eliminating all except 1 reaming operation.

PROOF POSITIVE

The illustrated cam originally required 7 parts, individually machined out of cold rolled steel, and then assembled by brazing.

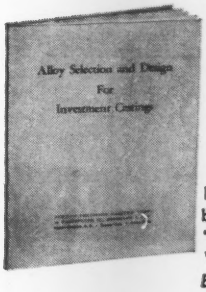
ARWOOD ENGINEERS

Redesigned the part to incorporate all 7 parts into one casting. What's more the alloy was changed to give improved service and longer life... all at substantial savings.

PART NO. 90267 (Assembly)
METAL ... Cold Rolled Steel
PARTS ... 6 Cams, 1 Shaft
1) Shaft — turned, drilled, faced and slotted from bar stock
2) Cams — profiled, drilled and reamed
ASSEMBLY ... By brazing
FINISHING ... Finish grind cam surfaces

REDESIGNED AS CASTING (SINGLE UNIT)
METAL ... Beryllium Copper
PARTS ... Single Casting
FINISHING ... Ream Shaft & Heat Treat
EST. SAVINGS ... Tools 60%, Finished Part 40%

WOULD YOU LIKE TO INVESTIGATE?



Let our engineers show you how to apply the precision casting process in your industry, so your company can also realize substantial savings in money and production time. Drop us a line and we will have one of our sales engineers call on you.

★

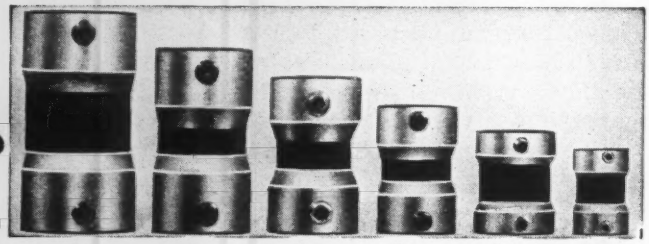
If you would like further information about the process before requesting our representative, write for our booklet, "Alloy Selection and Design for Investment Castings." *We also recommend the book "Investment Castings for Engineers", published by Reinhold Publishing Corp.*

ARWOOD

PRECISION CASTING Corp.
78 WASHINGTON STREET B'KLYN 1, N. Y.
Plants: Brooklyn, N. Y. · Groton, Conn. · Tilton, N. H. · Los Angeles, Cal.

"TO TRANSMIT NOISELESSLY..."

HERE...



specify Guardian FLEXIBLE COUPLINGS

Guardian "Dyna-Line" flexible couplings are solving drive problems in a wide variety of applications. Typical of these, with our No. 00-R from instrumentation to light pump and accessory drives, is the case history at the right.

The flex-element length, duro, compound and reinforcement all function to provide required flexibility and dampening. One-piece design means freedom from noise, lubrication and friction-drag, particularly in minor misalignment.

Our product application dept. will welcome consideration of your drive problem.

FROM OUR PRODUCT APPLICATION FILE

Case History No. 22—00

PROBLEM—A nationally advertised sewing machine required coupling *to transmit noiselessly* the 60 watt 6000 rpm of a cushion-mounted motor. The coupling must absorb misalignment to 1/16", yet provide steady power transmission without whip or backlash.

SOLUTION—Guardian Dyna-Line No. 00-R 2.25" long with standard Flex-Elements met all requirements. Length specified carried no "special length price".

Write for Catalog Page C102 and Drive Data Form #53.

Guardian PRODUCTS CORP.
COUPLING DIVISION
Dept. IC-M, 1215 E. Second St., Michigan City, Ind.

Guardian
QUALITY IS TRUE ECONOMY

TO CUT COSTS....

DON'T HAUL LIQUIDS....

PUMP THEM FAST

with a VIKING ROTARY PUMP

Whether your liquids are so thick they don't want to flow, or so thin they have to be kept in a closed system to keep from gasifying there's a Viking built in the size and type to fit YOUR needs.

½ to 1050 gallons per minute capacity range.
Over 600 cataloged models.
Thousands of special designs.
50 pounds maximum pressure per square inch on standard models.
250 pounds maximum pressure per square inch on heavy-duty models.
500 pounds maximum pressure per square inch on hydraulic oils.
All types of drive arrangement.

Get complete facts from your nearest Viking distributor or send for bulletin 54SH today.

See Our Catalog In SWEETS

VIKING PUMP COMPANY
CEDAR FALLS, IOWA

Men of Machines

of the Steel Products Engineering Co., in charge of engine development for the Navy. Mr. Sherman wrote an article entitled "Slant Mechanisms—Principles and Application," which appeared in the November 1947 issue of MACHINE DESIGN.

Grant H. Arrasmith recently joined the engineering staff of the Brake Shoe & Castings Div. of American Brake Shoe Co. at Mahwah, N. J.

Lawrence G. Maechtlen, vice president of the Square D Co., has been named manager of the company's western division in Los Angeles.

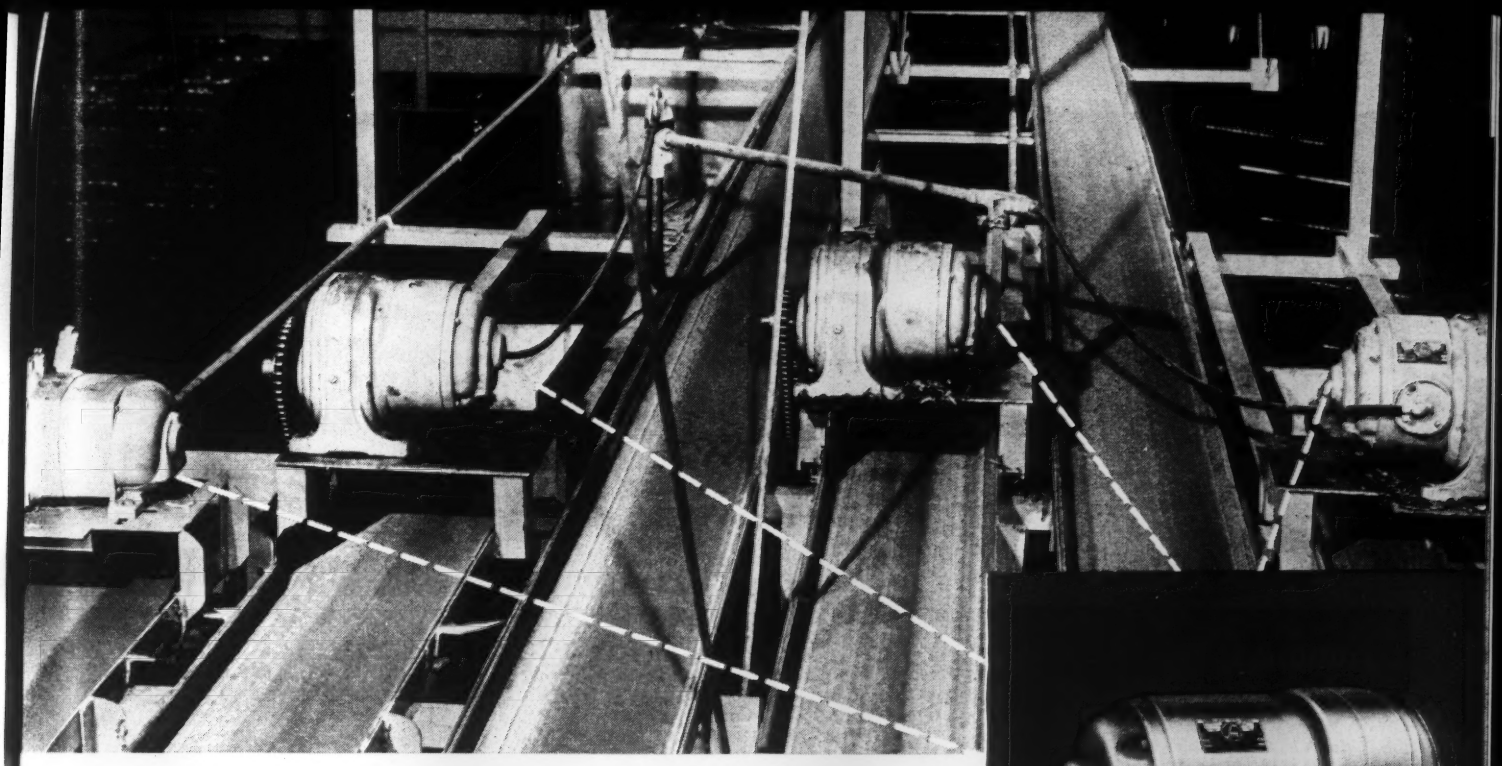
Formerly chief engineer, **L. E. Wells** has been named director of research and engineering for industrial products by the Electric Storage Battery Co., Philadelphia.

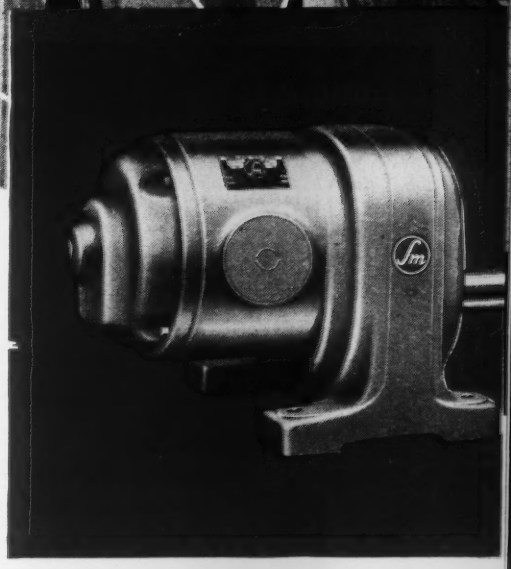
At a recent meeting of the board of directors of Geometric Stamping Co., Cleveland, **E. F. Carney** was elected vice president and general manager of the company.

Leonard M. Dorman recently joined Fluid Controls Inc., Mentor, O., as assistant general manager. He was formerly manager of the Plastics Div. of Talon Inc.

Morton Mfg. Co., Muskegon Heights, Mich., has announced the appointment of **Sherwood Basch** as acting chief engineer of the company and **Kenneth Oslund** as chief engineer of the welding division.

Carl E. Schmitz, vice president and general sales manager of the Crane Packing Co., Chicago, has been appointed director of the National Conference on Industrial Hydraulics for 1954. Under the guidance of Mr. Schmitz, this organization is fostering a model educational program to improve the use, application and maintenance of hydraulic equipment.





STERLING SLO-SPEEDS DRIVE CONVEYORS AT PAULUS BROS. PACKING CO.

Over 185 installations of Sterling Electric Power Drives during the past 10 years at Paulus Bros. Packing Co. are giving outstanding service... rugged, compact Slo-Speeds assure minimum maintenance, require minimum installation space, and their streamlined design permits easy, efficient cleaning which is so necessary in a cannery, reports G. G. Perkins, Mechanical Superintendent at Paulus.

INDUSTRY NAMES SLO-SPEED PRODUCTION ADVANTAGES

In a nation-wide user survey of Sterling Slo-Speed Geared Electric Power Drives:

86% Lowered Maintenance Costs. **56%** Increased Plant Safety. **76%** Reduced Lubrication Requirements. **56%** Obtained Better Protection Against Outdoor Exposure. **46%** Required Less Installation Space. **40%** Achieved Greater Cleanliness. **10%** Reduced Power Costs. **22%** Increased Production. **56%** Simplified Installations. **32%** Improved Employee Morale. **12%** Achieved Quieter Operation. **38%** Modernized Equipment and Machines for Better Performance, Better Appearance.

Investigate the possibilities of bringing some of these Slo-Speed production advantages to your plant. Sterling Engineering Sales Offices and over 400 Distributors and Service Shops throughout the nation effectively serve every industrial, commercial and agricultural area.

20-PAGE ILLUSTRATED CATALOG

Sterling Speed-Trol, Slo-Speed, Klosd and Klosd-Tite Electric Power Drives. Write for catalog No. D-424.

There Is a Sterling Electric Power Drive to Meet Virtually Every Requirement

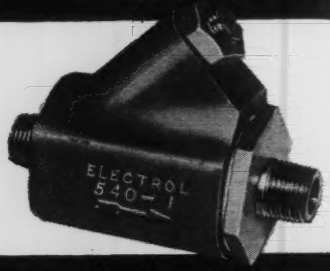
Sterling Speed-Trol Electric Power Drives—for variable speed at its best
Sterling Klosd and Klosd-Tite Motors—for constant normal speed at its best

STERLING ELECTRIC MOTORS

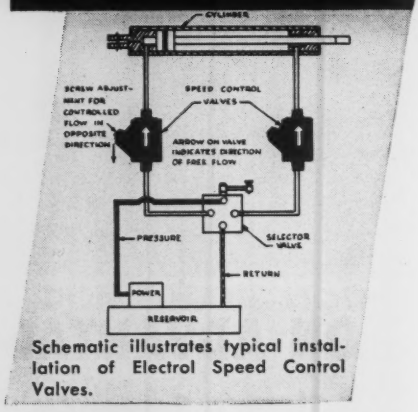
Plants: New York City 51 • Chicago 35 • Los Angeles 22 • Hamilton, Canada • Santiago, Chile

Offices and distributors in all principal cities

Electrol Speed Control Valves



Handle Air... Oil or Water with Operating Pressures up to 1,500 P.S.I.



Schematic illustrates typical installation of Electrol Speed Control Valves.

Electrol Speed Control Valves are designed to handle air . . . oil or water with operating pressures up to 1,500 P.S.I. They allow free flow in one direction and—by use of a metering device and check valve— accurately control reverse flow from 0 to valve maximum, even after thousands of cycles. They are available with 1/8", 1/4", 3/8", 1/2" and 3/4" N.P.T. ports. Your inquiries will receive prompt attention.

Better Designed Products Use Electrol Hydraulics

Electrol INCORPORATED **HYDRAULICS**

KINGSTON, NEW YORK
Telephone, Kingston 1980

CYLINDERS • SELECTOR VALVES • FOLLOW-UP VALVES
CHECK VALVES • RELIEF VALVES • HAND PUMPS
POWERPAKS • LANDING GEAR OLEOS • SOLENOID VALVES • ON-OFF VALVES • SERVO CYLINDERS • TRANSFER VALVES • CUT-OUT VALVES • SPEED CONTROL VALVES

Stress Relief

SPRING is here, but instead of a cheery song, a mournful lament on a human-bird species is J. P. Henderson's greeting of the season.

The Early Bird and the Morning Mail

I remember very well one employee who used to haunt my office. I called him (mentally) the Early Bird, and if a supply had been handy, gladly would I have fed him worms.

Nearly every morning as soon as I entered my office Early Bird came catapulting through the doorway, papers in his hand and a triumphant grin on his face.

"Good morning, chief," says he. "Just thought I'd get you before you got involved in the day's work."

Hanging up my coat, I'd think —what do you mean before I "got involved in the day's work"? What are you doing but involving me?

I'd take a quick look at my desk and sit down. There was the morning mail in two neat piles. Opened letters on this pile, with one still unopened which my secretary interpreted as personal; lower grade stuff on the second pile.

"Sit down," I'd say reluctantly.

"Well, chief, it's like this . . ."

I'd steal a glance at the unopened letter. What was the postmark? Rockford. Who did I know there, I'd think, ungrammatically. Underneath was a letter from the New York office. Were they reporting on that special unit we had sold? I got a glimpse of a letter from Charley in Duluth. What was worrying him?

What was this character trying to tell me? Relucantly I gave him half attention, my mind still intrigued by the pile of mail.

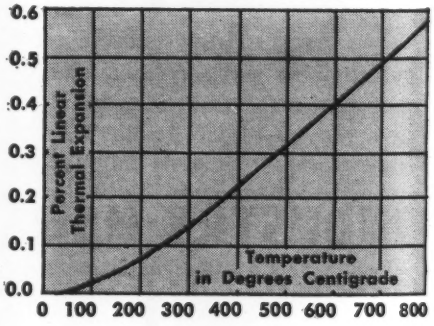
"Look, Early—I mean Jack—why don't we discuss this later? I'll give it a little thought and

how HOT can ENGINEERED CERAMICS . . . . get?

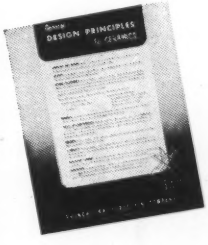
At temperatures that would melt elements like Titanium (1800° C.) or Platinum (1773° C.) FRENCHTOWN ALMANOX, 95% Alumina Ceramic, will not begin to soften —not until the temperature hits 1927° C.

Even the softening temperature of 1649° C. for FRENCHTOWN #7873, 79% Alumina, far exceeds the melting points of Chromium, Iron, Cobalt, Nickel and other metals.

LINEAR THERMAL EXPANSION OF ALMANOX (95% ALUMINA)



Not only the remarkable heat resistance of Alumina Ceramics but low thermal expansion (like that of Almanox shown above) presents wide design possibilities whether for mechanical, electrical or electronic applications.



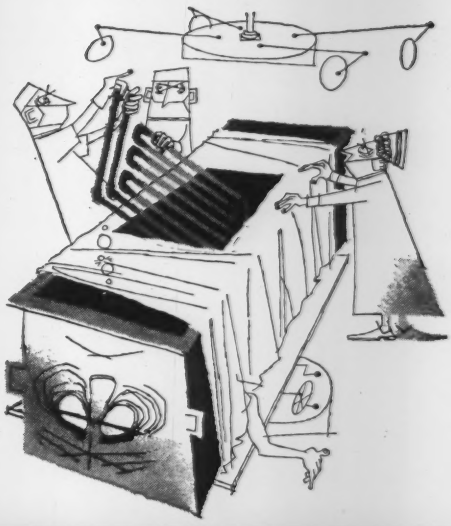
For complete information, send for this bulletin on Design Principles and chart of electrical and mechanical properties of FRENCHTOWN ENGINEERED CERAMICS.

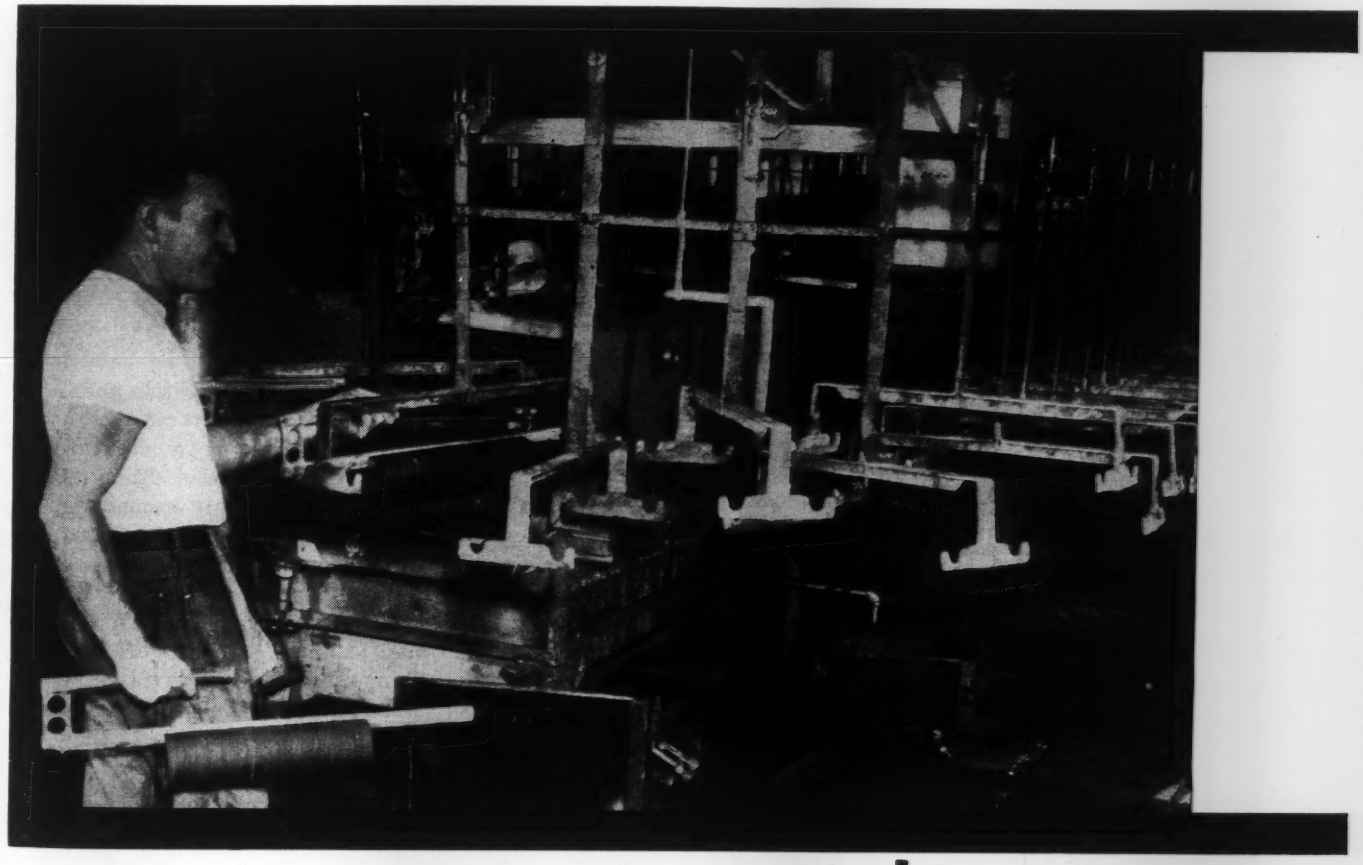
Frenchtown PORCELAIN COMPANY
88 Muirhead Ave. . . . Trenton 9, N.J.

coil-itis* cured — chipping eliminated by PLATECOILS to save 6 to 8 hours daily

Use of Stainless Steel Platecoils in a phosphate coating tank at Sealed Power Corporation has completely eliminated a 6 to 8 hour a day chipping job. The brass pipe coils formerly used became so coated with scale they had to be cleaned daily.

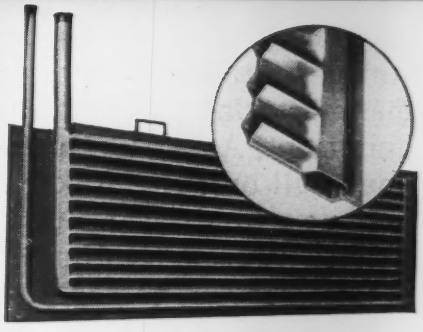
Three Platecoils heat this tank as efficiently as four pipe coils and maintain desired temperatures throughout both shifts. Scale removal, when necessary, takes less than two manhours compared to 10 hours for pipe coils.



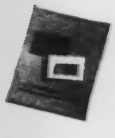


PLATECOILS replace pipe coils for 50% of the cost

* Coil-itis is the constant doctoring of wet processing tanks for pipe coil troubles. It can be cured easily by replacing pipe coils with Platecoils. Immediately, you will notice the difference as Platecoils put new life and profits into your heat transfer processes. They heat or cool 50% faster and take 50% less space in the tank. They save as much as 50% in initial cost and 50% in maintenance costs in addition to overcoming the limitations and operating difficulties of old fashioned and outmoded pipe coils.



Bulletin P71 shows how Platecoils are replacing pipe coils at a savings throughout industry. Send today for your copy.



Platecoil Division, TRANTER MANUFACTURING, inc., Lansing 4, Michigan

For fast shipment see your local distributor

What's your cylinder problem?

Big one: Anker-Holth Rotating Hydraulic Cylinder with 21" bore and 20" stroke, for 3000 psi. Little one: Anker-Holth Air Cylinder with 3" bore, 3" stroke.

Anker-Holth has the answer!

• Your problem in power motion may be far removed from the Anker-Holth Cylinders shown above. Whatever your need for air or hydraulic cylinder power, Anker-Holth has the engineering know-how and manufacturing facilities to match your specific requirement. Anker-Holth engineers will gladly assist you. Call or write Anker-Holth Division of The Wellman Engineering Company, Dept. A-8, 2723 Conner Street, Port Huron, Michigan.

FREE on request... bulletin on complete line of Anker-Holth products.

Anker-Holth
ENGINEERED CYLINDER POWER
WELLMAN
Division of THE WELLMAN ENGINEERING COMPANY

Stress Relief

we'll get together."

"O. K. But there was one other little item . . ." And off he'd go again.

This type I found almost incurable. After offering hints over a period of time and with no effect I finally decided to reveal myself as a cantankerous old woman and take a firm hand.

So on the next bounding visit from him I explained. "Jack, I'd like to look over my mail first this morning. Why don't you come back in about fifteen minutes?"

"O. K., chief," says he. "There are several items we can talk over in detail then. But there's this one little item I'd like to mention now."

Listening with one ear I'd fiddle with that interesting stack of mail. And months later we were still going through the familiar routine.

"Look, Jack, I'd like to glance over this mail . . ."

"O. K., chief, I'll be back later but there's this one little point. . ."

How obtuse can a man get?

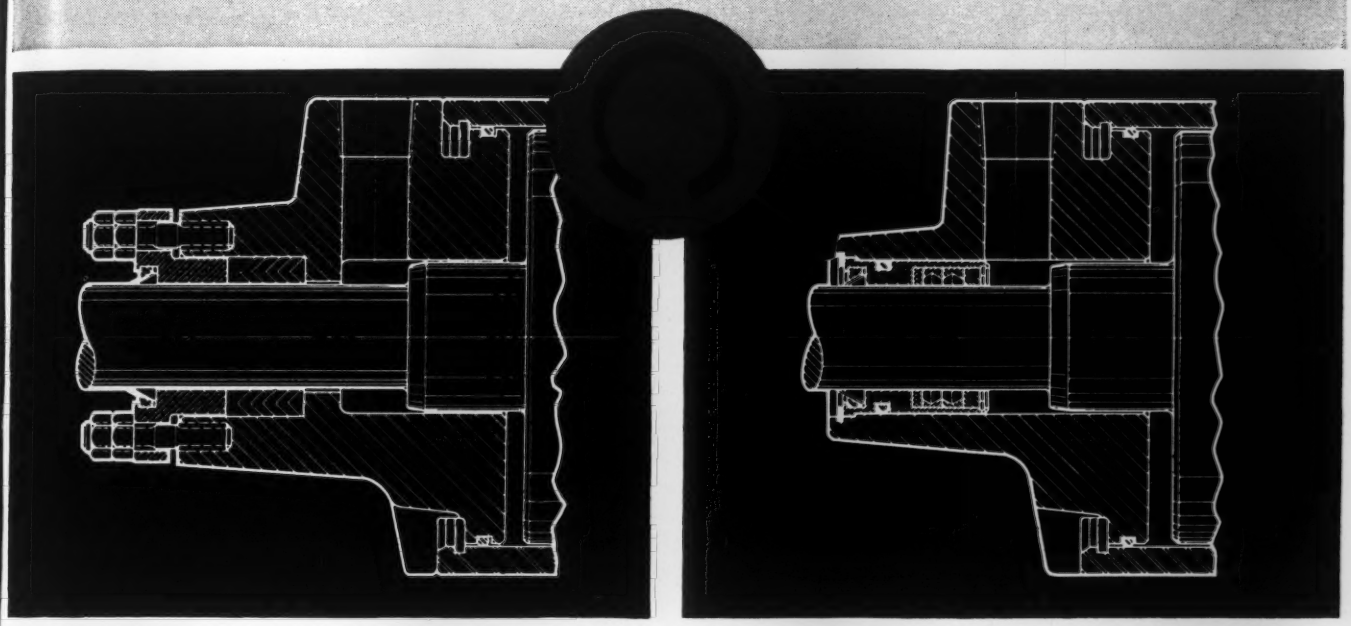
Actually I was a creature of habit, just as was Early Bird. Years ago over my second cup of breakfast coffee I had started the practice of reviewing the office happenings of the day before. What had been left undone that I had planned? What were the first things I had to do today? What were some of the other items and in what order should they be tackled?

Those details were all pretty well outlined by the time I reached the office. Some new problems were presented by that stack of mail. Certain of those letters might need immediate attention. Their problems had to be integrated with the plans I had made for the day. Once that reshuffle was accomplished mentally, I could face the day in an orderly manner. Except for the usual interruptions I had a pattern of activity to follow permitting me (perhaps) to go home at night with the major chores accomplished.

It was this ingrained habit, vital to my peace of mind that Early Bird was upsetting.

One time I visited a customer and was met at the airport by

Waldes Truarc Ring Saves $2.84 Per Unit, Cuts Labor-Time and Materials in Hydraulic Packing Unit



OLD STYLE stuffing box required skilled worker to install packing rings one at a time, then adjust packing glands by trial and error. Disassembly was equally difficult, time-consuming and costly.

NEW Monopak Cartridge is smaller, lighter, streamlined and installed with one Truarc Retaining Ring. Disassembly and reassembly with new cartridge takes unskilled worker just 1 minute.

Hydraulic Accessories Company of Van Dyke, Michigan, uses a single Waldes Truarc Inverted Ring (internal series 5008) to hold Monopak Cartridge in cylinder head.

New design eliminates costly machining and saves 2⅛ lbs. of material. Re-design with Waldes Truarc Retaining Ring reduces stuffing box diameter from 3½" to 2⅞", and reduces length from 5⅞" to 4⅜". Allows savings in assembly, adjusting and testing.

NEW DESIGN USING WALDES TRUARC RING PERMITTED THESE SAVINGS PER UNIT

MACHINE TIME SAVED:	
Chucking, facing and boring	$ .72
Drilling and tapping 3 holes	.18
Drilling and counterboring 3 holes	.12
Assembling, adjusting, testing	.90
MATERIAL SAVED:	
1½ lbs. cast iron	.30
½ lb. bronze	.23
3 studs	.36
3 nuts	.03
TOTAL	**$2.84**

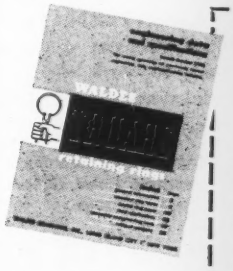
Waldes Truarc Retaining Rings are precision-engineered . . . quick and easy to assemble and disassemble. Always circular to give a never-failing grip. They can be used over and over again. There's a Waldes Truarc Ring to answer every fastening problem.

Find out what Waldes Truarc Retaining Rings can do for you. Send your blueprints to Waldes Truarc engineers for individual attention, without obligation.

For precision internal grooving and undercutting . . . Waldes Truarc Grooving Tool.

"See the Waldes Truarc exhibit at the A.S.T.E. Show, April 26-30. Booth No. 424, Precision Hall."

SEND FOR NEW CATALOG



WALDES

TRUARC

REG. U. S. PAT. OFF.

RETAINING RINGS

WALDES KOHINOOR, INC., LONG ISLAND CITY 1, NEW YORK

WALDES TRUARC RETAINING RINGS AND PLIERS ARE PROTECTED BY ONE OR MORE OF THE FOLLOWING U. S. PATENTS: 2,382,947; 2,382,948; 2,416,852; 2,420,921; 2,428,341; 2,439,785; 2,441,846; 2,455,165; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,509,081 AND OTHER PATENTS PENDING

Waldes Kohinoor, Inc., 47-16 Austel Place, L.I.C. 1, N.Y.

Please send me the new Waldes Truarc Retaining Ring catalog.

MD 046

(Please print)

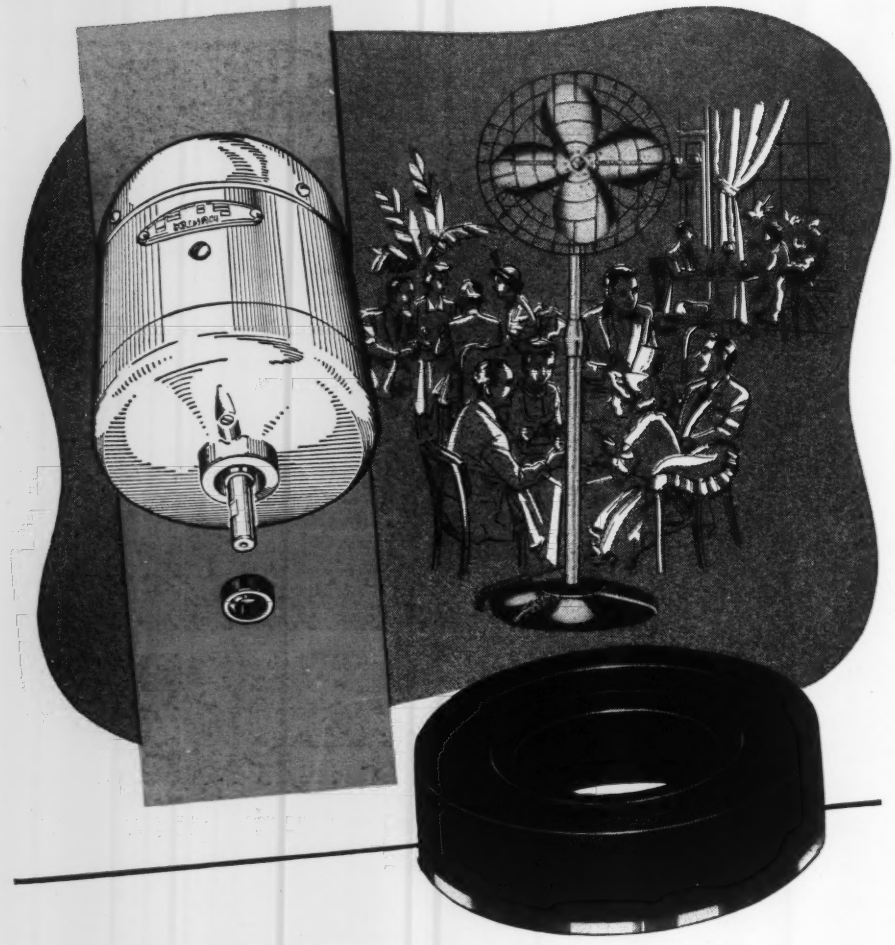
Name.....

Title.....

Company.....

Business Address.....

City..... Zone..... State.....



How G&K INTERNATIONAL helps Hunter Fan & Ventilating Company keep *Oil* where it belongs

Oil — in the wrong place — can be a problem, particularly on a fan spindle revolving at 1125 rpm.

Hunter Fan and Ventilating Company, Memphis, Tenn., were using a case seal with garter spring as the oil retainer on the spindle of their 24" and 30" Airspread Fans. Since these fans are used in churches, restaurants, auditoriums, industry . . . oil leakage and spattering had to be eliminated.

G&K-INTERNATIONAL engineers suggested the use of a bonded-washer-type oil seal of molded synthetic rubber specially formulated to maintain a close seal under the severe conditions of service. Lower cost and ease of assembly were added attractions . . . in fact, the solution appeared too good to be true! But severe performance tests proved that the G&K-INTERNATIONAL oil seal eliminated oil creep, even when the oil cavity was overloaded.

G&K-INTERNATIONAL is ready to work with your engineers . . . to supply standard and special synthetic rubber packings of all types; also modern leather U's, V's, Flanges, Cups and Oil Seals.

Write for G&K-INTERNATIONAL Catalog and Manual 201-A. 60 pages of up-to-date data including latest JIC and officially recommended sizes for all types of packings.

G&K-INTERNATIONAL *Packings*

GRATON & KNIGHT

LEATHER—SYNTHETIC RUBBER

P-2

GRATON & KNIGHT COMPANY, Worcester, Massachusetts
INTERNATIONAL PACKINGS CORPORATION, Bristol, N. H.

Stress Relief

their chief engineer. We had breakfast together and then drove out to his office.

There on his desk were two stacks of mail. Before hanging up his hat he went over and shuffled through them, a preoccupied expression on his face.

"Look," I said, "Why don't you tell me where the washroom is, and I'll go there while you look over the mail."

From the smile on his face, it was obvious that we were both going to be relieved by this arrangement.

—J. P. HENDERSON

They Say . . .

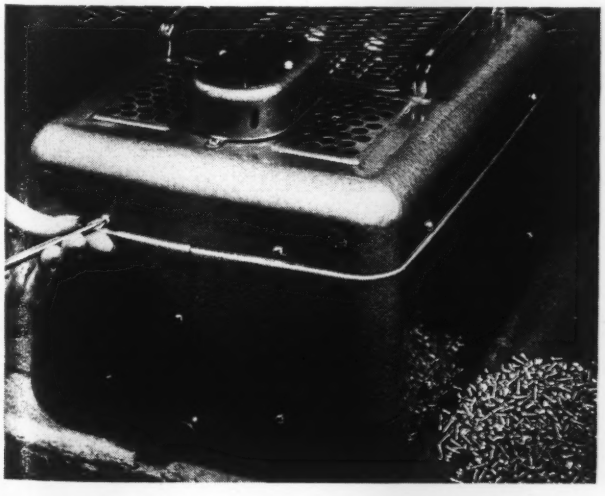
"It is a striking fact that seventy thousand scientists and fifty-five thousand engineers, or a total of one hundred and twenty five thousand men and women, carry the research load of the United States. Of this total about sixty per cent are in private industry, thirty-three per cent in government, and about seven per cent in universities and nonprofit institutions. This is an exceedingly small fraction of our total working population, and its smallness points up the importance, first of preserving an atmosphere and environment in which this group can be supremely effective, and second, of making certain that we maintain a steady flow of first rate minds to the group."—DR. LEWIS K. SILLCOX, *president, ASME.*

"A creeping growth of control by the military over an increasing segment of the manpower and brainpower of this country is a dangerous fact that needs immediate recognition by the American people. Over 25 per cent of all engineers and scientists engaged in research and development programs in the country—the very people on whom we depend for our continued technological and economical superiority — could be placed in uniform tomorrow with a snap of the Pentagon's official finger."—DR. T. H. CHILTON, *chairman, Engineering Manpower Commission of Engineers Joint Council.*

Users praise Phillips Cross-Recessed-Head Screws

BUCHANAN'S pres-*SURE*-tool is here assembled with Phillips screws by Harold Kennedy. "We simply cannot afford to have our products 'gummed up' by unsightly burrs and mutilated heads," says Albert Mittleman, Plant Superintendent and Production Manager. "It was this feature more than any other which so completely sold us on Phillips screws that we will continue to use them in all new products wherever design permits."

YANKEE METAL PRODUCTS' SEALED BEAM FOGLIGHTS are fastened with Phillips SEMS. "Increased production was immediately evident," says L. Fleischman, production manager, "in that the self-centering feature of the Phillips head made possible the application of power screw drivers. The high percentage of misses and rejects was eliminated. We have been using Phillips head screws since 1936 and we would most definitely not use any other type."



THE HIGH ENAMEL FINISH OF TITAN'S THERM-O-DIAL HEATERS is in no danger of costly damage when Phillips screws are used. "With ordinary screws," Richard K. Fleischman, Titan vice-president, points out, "driver slippage and insecure gripping of the driver bit enforced additional hardships on the driver tools themselves. Drivers last indefinitely with Phillips screws."

MANUFACTURERS OF PHILLIPS CROSS-RECESSED-HEAD SCREWS

THE FASTENERS OF TODAY... AND OF THE FUTURE

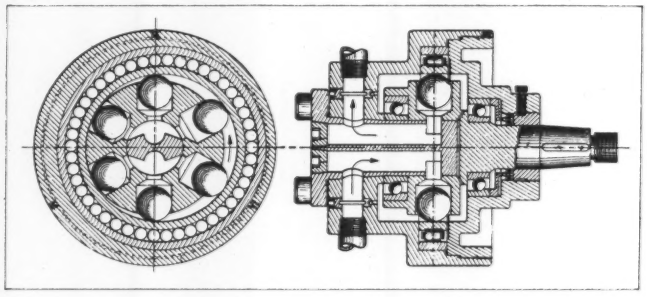
X marks the spot

... the mark of extra quality

American Screw Company • Atlantic Screw Works, Inc. • The Blake & Johnson Co. • Central Screw Company • Continental Screw Company • The Eagle Lock Company Elco Tool and Screw Corporation • Great Lakes Screw Corporation • The H. M. Harper Co. • The Lamson & Sessions Company • National Lock Company • The National Screw & Manufacturing Co. • Parker-Kalon Div. General American Transportation Corporation • Pheoll Manufacturing Co. • Rockford Screw Products Co. • Scovill Manufacturing Co. • Shakeproof • The Southington Hdwe. Mfg. Company • Sterling Bolt Company • Wales-Beech Corp.

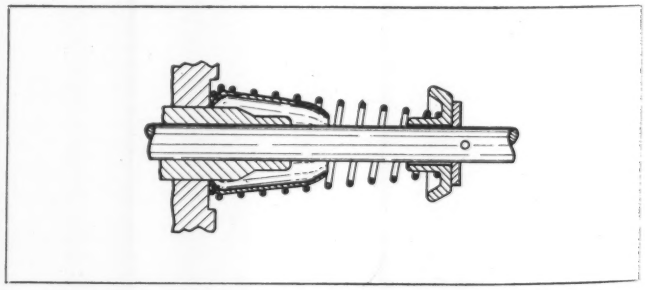
NOTEWORTHY Patents

BALL PISTONS reduce friction and facilitate high-speed operation in a hydraulic pump design detailed in patent 2,646,755. Designed by Joseph Joy and assigned to Joy Mfg. Co., the pump employs spherical metal pistons mounted in radial cylinders in the pump rotor to create pumping and suction actions. As the rotor revolves, the pistons bear against a track ring, mounted on antifriction bearings and offset to the rotor axis, and are reciprocated in and out in their



bores to produce a complete pumping cycle. Flow through the pump is controlled by a stationary valve arrangement which guides the fluid between two opposed intake and exhaust ports. Readily adapted for use as a motor, the design can be operated at high speeds without danger of fluid voids or overheating. Several modifications of the unit to meet different control and performance requirements are also covered in the 36-page patent.

FRICTIONAL VIBRATION DAMPING of coil springs prevents surging under load and simplifies damper construction and installation. Designed by John L. Sjolander, the damper covered in patent 2,650,086



consists of a sheet-metal blank formed in a conical shape for insertion into the large end of a conical spring. Contact of the spring coils with the resilient sheet metal surface produces a frictional damping

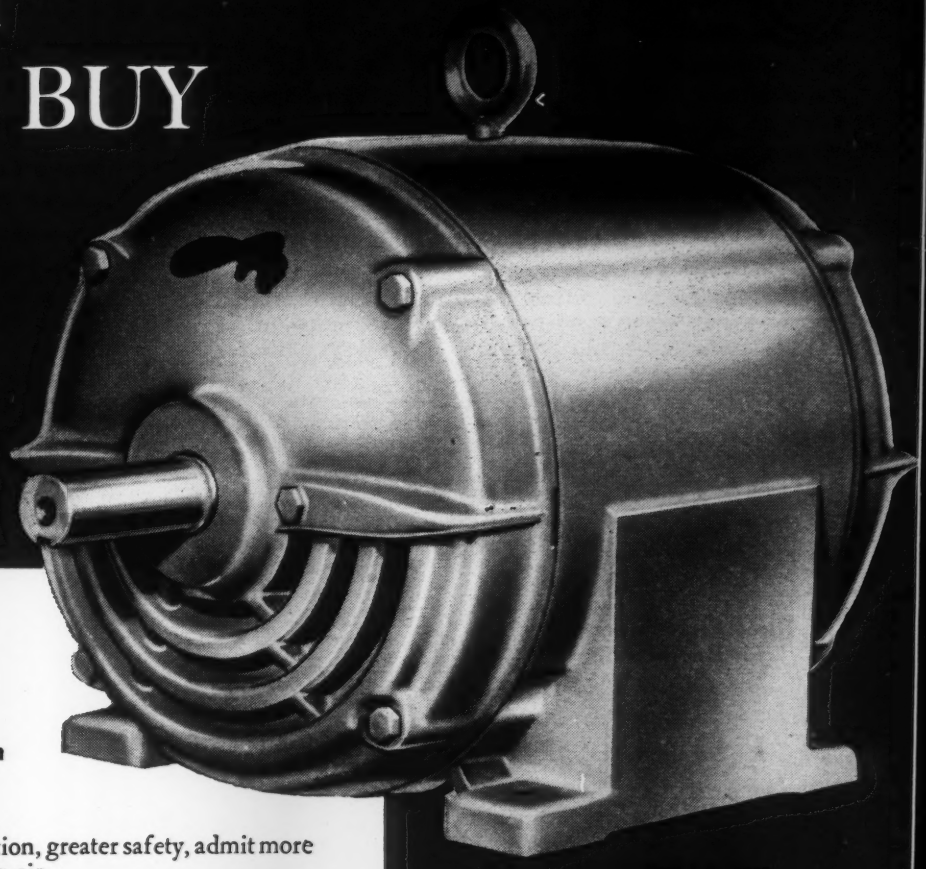
Here's why

the NEW L.A. *Line*

by the Louis Allis Co.

is your BEST *electric motor* BUY

A smaller, better power package to meet new NEMA standards



with NEW MODERN STYLING

plus

Improved ventilation
New conduit-box arrangement
New bearing construction
More compact design and better protection
More versatile mounting

Here you have complete use of modern motor materials, design techniques and new manufacturing methods. You also get more power in a smaller package — and clean, streamlined motor styling to add modern appearance to the equipment these new motors drive.

This new styling is completely functional. Ventilating grilles, for example, blend into the general motor design — yet they provide better protection, greater safety, admit more cooling air.

Completely enclosed housing provides protection for the new L.A. line in any mounting position — floor, sidewall, or ceiling.

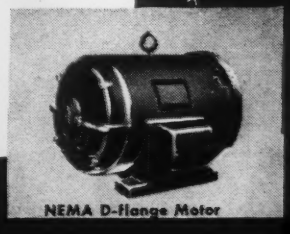
Standardize now on the new L.A. line for both your product and your plant — and get the most modern motor construction available. See your nearby Louis Allis Sales Engineer today for the complete story.

Vertical NEMA C-flange Motor

THE LOUIS ALLIS CO.

Milwaukee 7, Wisconsin

LA-102



NEMA D-flange Motor

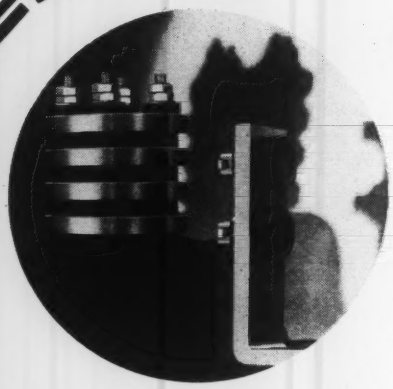
We specialize in SPECIAL MOTORS — *and* PROMPT DELIVERY, TOO

NEMA C-flange Motor

There's a Louis Allis special motor for your application. Tell us the electrical or mechanical modifications you need, check here with [illegible]

COLLECTOR RINGS

to your specifications



For Electric Roll Heater

Wesche Collector Ring assemblies are usually designed and built for a specific application. They serve to complete electric circuits between stationary and revolving parts.

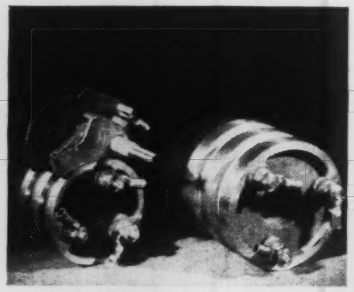
Typical applications are electrically heated rolls, revolving platforms or cranes and rotating parts on machinery.

Welco Collectors are assembled with bronze rings insulated from each other with phenolic or fibre. The required number of terminals extend from one or both ends. Two to more than forty rings may be assembled into a single unit with ratings from fractional to more than 200 amperes.

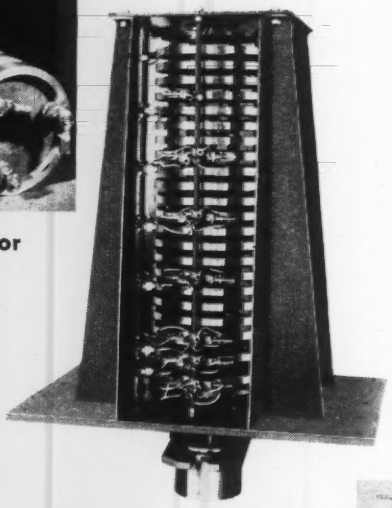
Rings for Thermocouples are made of silver to reduce contact drop. Rings are made up to 48″ diameter and can be supplied split for mounting on existing machinery, such as shovels, cranes and bridges.

Space limitation is one of the deciding factors in the design of a suitable collector.

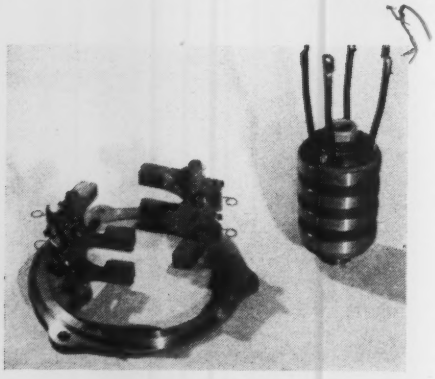
Our catalog contains a data sheet which makes it easy for you to furnish complete information on your requirements.



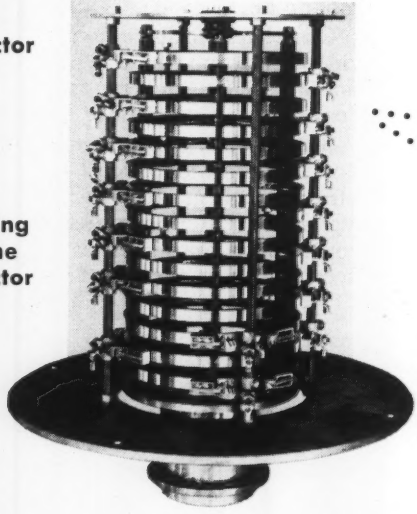
Three Ring Collector for Radial Drill



22 Ring Crane Collector



4 Ring Radial Drill Collector



15 Ring Crane Collector

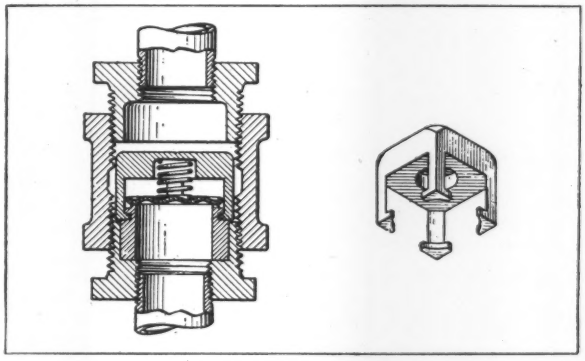
Write ***today for your free copy of this catalog containing data sheet and specifications for a group of standard design rings.***

THE B. A. WESCHE ELECTRIC CO.

1620 VINE ST. CINCINNATI 10, OHIO

action to absorb spring vibrations. In addition, the conical shape of the damper serves to position the spring in operation and facilitates assembly and maintenance. Assignee of the patent is Cleveland Wire Spring Co.

ONE-WAY FLOW CONTROL for hydraulic systems is obtained with a check valve employing a standard pipe-line coupling as the valve body. Described in patent 2,649,277 assigned to Durabla Mfg. Co. by R. H. Blackford, the valve can be mounted in any angular position without affecting its operating characteristics. Valve operation is controlled automatically by fluid flow; a spring-loaded metal disk is actuated to uncover a central opening when flow is in one direction and returns to the closed position when flow is stopped or reversed. Disk movement is restricted by a four-legged cage guide which acts as the spring retainer and prevents dislodging of the disk.

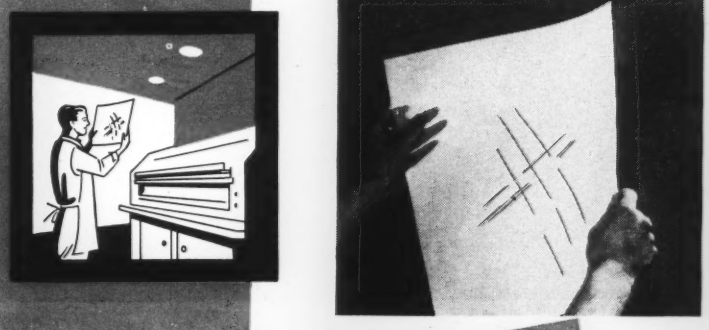


FLUID-TIGHT SEALING of rotating shafts is afforded by a one-piece seal which can be mounted from the side for easy assembly. Designed by Thomas O. Kosatka, the seal shown in patent 2,647,777 is intended for use with a shaft and housing and consists of a split metal-reinforced rubber sealing element which opens about a hinged construction to facilitate assembly. One lip of the seal engages the shaft and an outer U-shaped lip fits a mating flange on the housing. Sealing pressure is provided by compression of the rubber element which is thicker than the shaft-to-housing opening. Rotation of the seal on the shaft is prevented by the increased friction forces, due to a greater area of contact, at the housing. A modified construction for axial assembly is also shown in the patent which has been assigned to Victor Mfg. & Gasket Co.

VARIABLE-PRESSURE SEALING of rotating shafts is accomplished with a shaft seal designed by W. H. Coopman. It utilizes a floating sleeve to accom-

(*Concluded on Page* 384)

SEEING is BELIEVING!



To prove it's best, make the Clearprint test

SPECIFY:
No 1025 PAPERCLOTH-The Paper with Cloth Durability.
No. 1000H CLEARPRINT-The Universally Accepted Technical Paper.
Papercloth is available in widths from 24" to 54".
Ask for samples from your dealer, or write:

CLEARPRINT PAPER CO.
1482 SIXTY-SEVENTH STREET · EMERYVILLE, CALIFORNIA

Save yourself work—and safeguard your work—with Clearprint PAPERCLOTH. This simple test with a Papercloth sample shows you why thousands of engineers prefer it to tracing cloth.....

1. **INVITES PENCIL AND PEN**—Try Papercloth's perfect working surface with a 2H pencil, then with a ruling pen. Lines are clean and sharp, and surface remains unchanged.
2. **NO GHOSTS**—Erase some of the lines. Re-ink and erase several of them time and again without fear of feathering. Fold the sheet repeatedly, too. Then hold it to the light, or make cleanest possible reproductions.
3. **NEVER CHANGES**—Tough yet transparent, Papercloth never discolors, becomes brittle, or loses its transparency. Protects your drawings from the ravages of time and repeated handling.

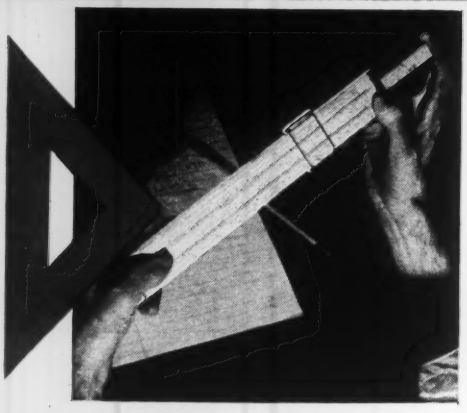
If you are not using Papercloth now, please make this comparative test on the paper or tracing cloth you are using.

CLEARPRINT®
PAPERCLOTH®

THERE IS NO SUBSTITUTE—Look for Watermarked Clearprint

Why does the PARAGON® "up" drafting room output, and easier for

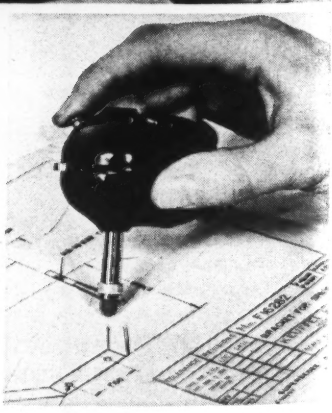
THE RIGHT ANGLE



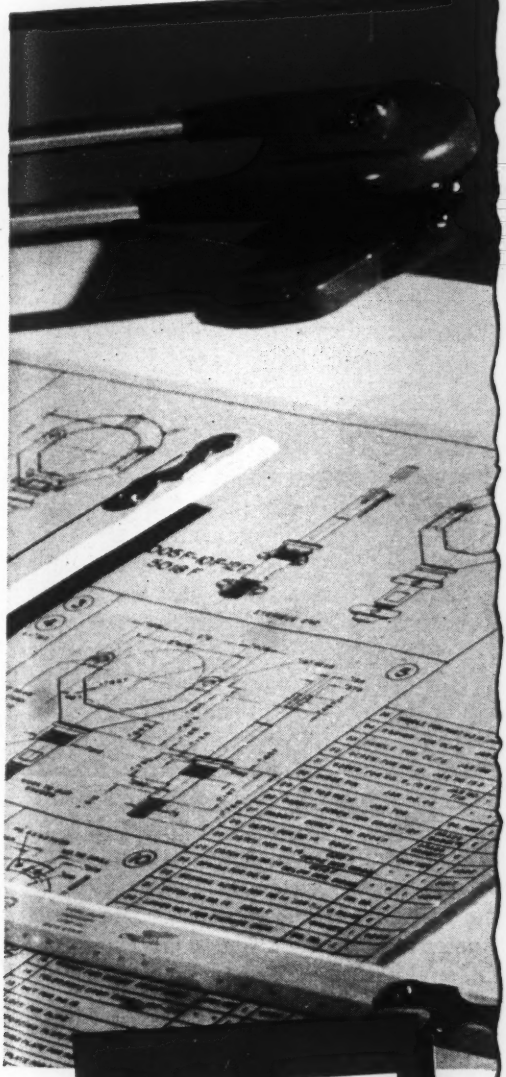
The first American-made slide rule was a K&E, and generations have known these rules for their precision, readability and velvet-smooth operation.

After you've once used a K&E MOTORASER,† you'd no more go back to hand erasing than you'd take to drawing with your gloves on.

†Trade Mark



make life draftsmen?

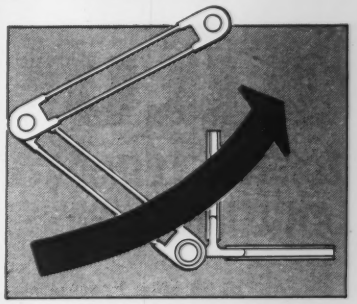


K+E

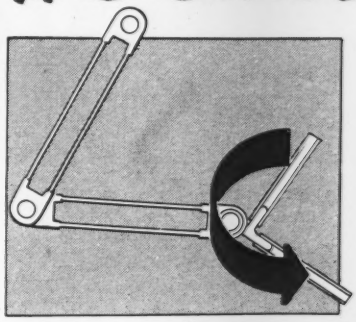
partners in creating

Because it's FAST

The Paragon Drafting Machine operates on the basic parallelogram principle. Three drums of precisely equal diameter are fitted with non-slipping bands. Top drum is fixed so that it cannot turn. Wherever you move the Paragon over the entire working area, you can draw precisely parallel lines: horizontal, vertical, or at any angle.



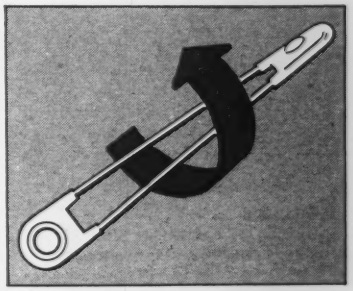
It's CONVENIENT



The Paragon is controlled entirely with your left hand, leaving your right hand free to draw. A slight pressure on the control ring gives you any common angle and its complement. All lines are drawn to exact length as you go, with no "tails" to erase later. When you're not using your Paragon, you simply park it out of the way on the anchor step.

It stays ACCURATE

Open-center arm construction, with no rigid center member, makes it practically impossible to disturb band length and factory-set tension. Even when the arms are twisted somewhat, as they must be when the head is lifted off the board, the dimensions of the rigid tubes and assembly remain unchanged. Scales continue to make exactly parallel lines straight out to the end.



It CUTS COSTS too

The Paragon eliminates hundreds of waste motions that the draftsman would have to make with hand equipment. It stays true and easy to operate throughout its entire life. It pays for itself in a matter of weeks, continues to cut costs over the years!

That's Why We Say . . .

IT'S QUICKER, EASIER, NEATER, WITH A PARAGON!

KEUFFEL & ESSER CO.

Est. 1867

NEW YORK, N. Y. HOBOKEN, N. J.

CHICAGO • ST. LOUIS • DETROIT • SAN FRANCISCO • LOS ANGELES • MONTREAL

When it has to Run for Years and Years

WITHOUT FAILURE!

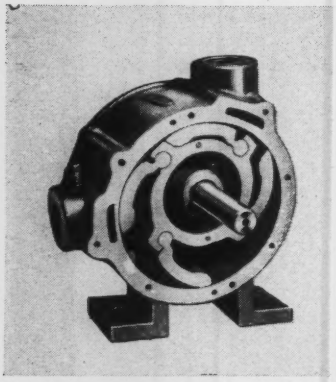
SPECIFY A LEIMAN VACUUM AND PRESSURE PUMP

Put Leiman in Your Product Designs And Get Customer Reactions Like This:

"Operating for 12 years without requiring any maintenance attention whatsoever except for lubrication."

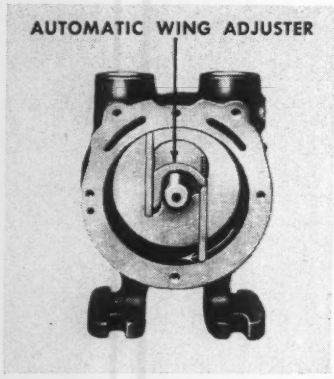
"They never wear out—never give trouble."

"We've had a Leiman pump in almost continous operation, 24 hours a day, for the last 21 years. It's as nearly noiseless as a pump can be . . . absolutely reliable in every respect."



4-WING TYPE

Vacuums to 20"; pressures to 15 lbs.; displacement to 162 cfm. Wings hinged to piston—centrifugal force maintains close, continuous contact to cylinder wall. Wings take up their own wear, insure positive pressure or vacuum. No composition material to require frequent renewal. Air chamber is large because of small piston size, giving unmatched capacity for size and weight of pump.



2-WING TYPE

Vacuums to 29.9"; pressures to 25 lbs.; displacement to 40.8 cfm. Blades cannot stick, because of exclusive Leiman automatic wing adjusting lever which forces each blade to meet cylinder wall, insures positive pressure or vacuum. Only steel blades (no composition) are used. They take up their own wear, deliver years of trouble-free service.

Look to Leiman in designing products like vacuum packing and filling machines . . . paper feeding agitators . . . vacuum chucks . . . liquid transfer equipment . . . or any other device requiring continuous, non-pulsating flow of air for vacuum or pressure.

Write for catalog and special bulletin on 60 representative applications.

SEE OUR CATALOG IN SWEET'S FILE

LEIMAN BROS., INC.

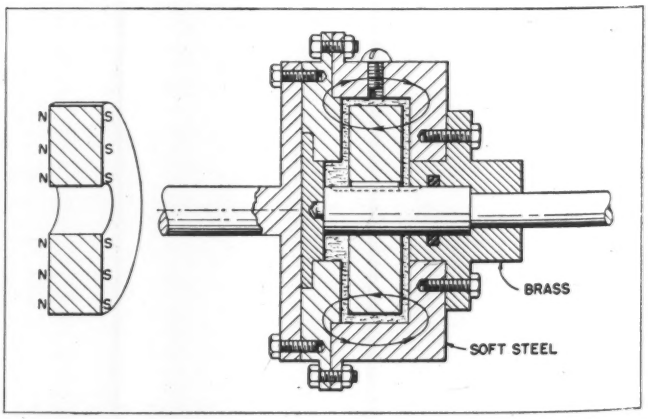
148 Christie Street **Newark 5, N. J.**

Noteworthy Patents

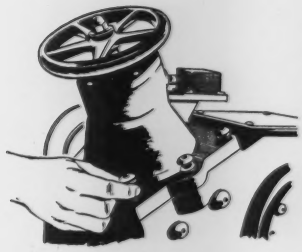
(*Concluded from Page* 381)

modate irregular thrust loads and end play. Effective under either high or low-pressure operating conditions, the seal described in patent 2,650,842 is designed for use with a shaft and housing or other similar combinations. Sealing action is provided by a flanged tubular sleeve which engages a stationary wear ring on the housing at the flanged end and fits into a counterbored collar on the shaft at the other end. In operation, the telescoping action of the sleeve, sliding in and out of the collar counterbore, serves to absorb end movements of the shaft. Sealing engagement of the wear ring and flange is maintained by fluid pressure under high-pressure conditions and by spring loading under low-pressure conditions. A modification of the design for continual high-pressure conditions is also shown in the patent which has been assigned to Cassman Mfg. Co.

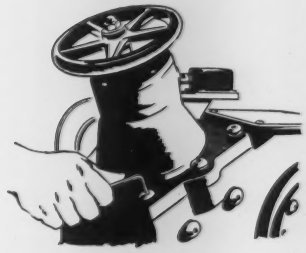
EXCESSIVE TORQUE PROTECTION for powered instrument drives, regardless of direction of rotation, is provided by a magnetic fluid clutch designed by J. F. English Jr. and A. J. Hornfeck and covered in patent 2,650,684. The clutch is designed for use with rotary drives employing a fixed stop or ratchet mechanism to control angular movement and will slip at a specified load to prevent damage to the drive components. Clutching action is produced by an Alnico disk magnet connected to the driving member which transmits power to a cylindrical driven housing through a solution of oil and iron particles. In normal operation, the freezing effect created by the action of magnetic forces on the fluid solution is sufficient to transmit torque. However, application of a sudden load due to contact of the driven member with a fixed stop or as a result of ratchet operation will cause the clutch to slip until load conditions are returned to normal. Torque capacity of the clutch may be varied through modification of the size and shape of the driving and driven elements and/or the composition of the oil-iron particle mixture. The patent, which also illustrates two modified constructions of the permanent magnet member, has been assigned to the Bailey Meter Co.



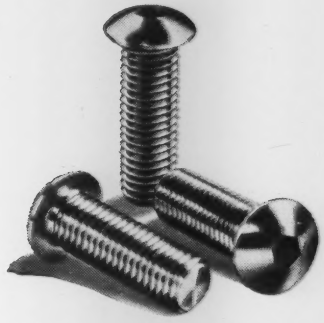
UNBRAKO **button head socket screws** are used exclusively to assemble this controlled volume pump, which was designed to fill the growing industrial need for the pumping of an allotted quantity of liquid at higher pressures, higher capacities.



The assembler inserts the UNBRAKO button head socket screw with his fingers, and runs it down as far as he can.



He then tightens it with a standard UNBRAKO key. Once seated, the low head design of the UNBRAKO button head provides a smooth, streamlined appearance.



UNBRAKO Button Head Socket Screws are made of heat treated alloy steel; have fully formed threads, Class 3 fit; are available in standard sizes from # 8 to ⅝". Accurate hex socket provides nonslip drive, prevents marring or mutilation of the head.

Save inventory dollars
Use UNBRAKO Standards—stocked by your distributor

Not only does your UNBRAKO distributor lower inventory investment, he also saves you time—and provides latest information about products, cost-saving methods, production techniques, current problems, trade practices. For latest data on UNBRAKO standard socket screw products, consult him or write STANDARD PRESSED STEEL COMPANY, Jenkintown 18, Pennsylvania.

See us at Booth 1539, Convention Hall, Philadelphia, Pa., during the A.S.T.E. Show, April 26 to 30.

UNBRAKO® **SOCKET SCREW DIVISION**

SPS JENKINTOWN PENNSYLVANIA

New Machines

Heating and Ventilating

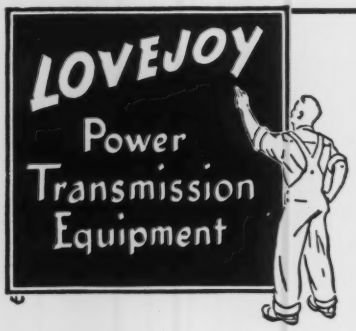
Heater-Cooler: Compact unit measures 42 in. wide, 29 in. deep, 70 in. high, requires 8.4 sq ft of floor space. Available in either gas or oil-fired models delivering up to 100,000 Btu and with either 2 or 3-ton cooling capacities. Combustion and heat-exchanger chamber is coated inside and outside with high-temperature glass. Nonvibrating compressor has pressure type oiling system, dynamically balanced crankshaft with removable cylinder liners. Water-cooled condenser is fabricated of finned copper tubing. Changing external pipe connection permits condenser's use with an alternate water pass arrangement, assuring low-pressure drops for wide range of condenser cooling-water temperatures. *A. O. Smith Corp., Milwaukee, Wis.*

Air Conditioners: Line includes 13 models in ⅓, ½, ¾ and 1-ton sizes. Installed in windows or through a wall, units extend 3 in. into room. Dial settings provide 18 different atmospheric conditions. All models dehumidify, ventilate, filter and remove stale air; permanent cleanable filters remove dust, dirt, soot and pollen before circulating air. Models range from 4300 to 11,500-Btu cooling capacity, removing 1.5 to 3.5 pints of water from air per hour. Several models have reverse cycle flow for heating. *Admiral Corp., Chicago, Ill.*

Air Cleaner: Ceiling-suspended home Precipitron electrostatic air cleaner is installed in the main return air duct of a forced-air heating system. It removes 90 per cent of airborne dust and pollen and is effective against smoke particles as small as 1/250,000-in. in diameter. Model PH-122 handles from 1000 to 1200 cfm of air; larger model PH-242 handles from 2000 to 2400 cfm of air. Water and drain line connections for washing away accumulated dirt are provided on both models. Major components are aluminum. Units operate on 115-v ac. *Westinghouse Electric Corp., Pittsburgh, Pa.*

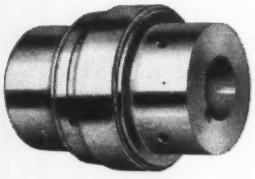
Materials Handling

Electric Fork Truck: Designed for tiering, with telescoping lift, and tilting, 10,000-lb capacity hydraulically operated truck has front wheel drive, rear wheel steer. Hoist unit consists of a single low-pressure hydraulic cylinder. Combination worm and spur gear drive and a fully articulating caster type trailing axle are employed for good maneuverability and easy steering. Hoist speed with full load is 15 fpm up, 35 fpm down. Overall length of truck without forks is 97 in.; height with uprights telescoped is 83 in., with uprights extended, 146 in. Equipped with

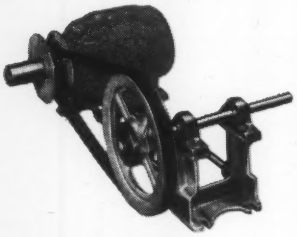


Economical In Cost
•
Easily Installed
•
Efficient, Long Lasting

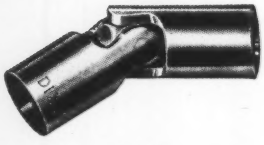
Send for catalog and engineering data



Flexible Couplings



Variable Speed Pulleys and Transmissions



Universal Joints

FLEXIBLE COUPLINGS:

No lubrication required. Provide positive protection against vibration, torque, shock of intermittent loads. Cushions changed without shutdown. Every duty from 1/6 to 2500 hp.

VARIABLE SPEED PULLEYS:

Quickly installed on new or old equipment. Change speed while machine is running. Ratios to 3 to 1. Fractional to 10 hp.

SELECT-O-SPEED TRANSMISSION:

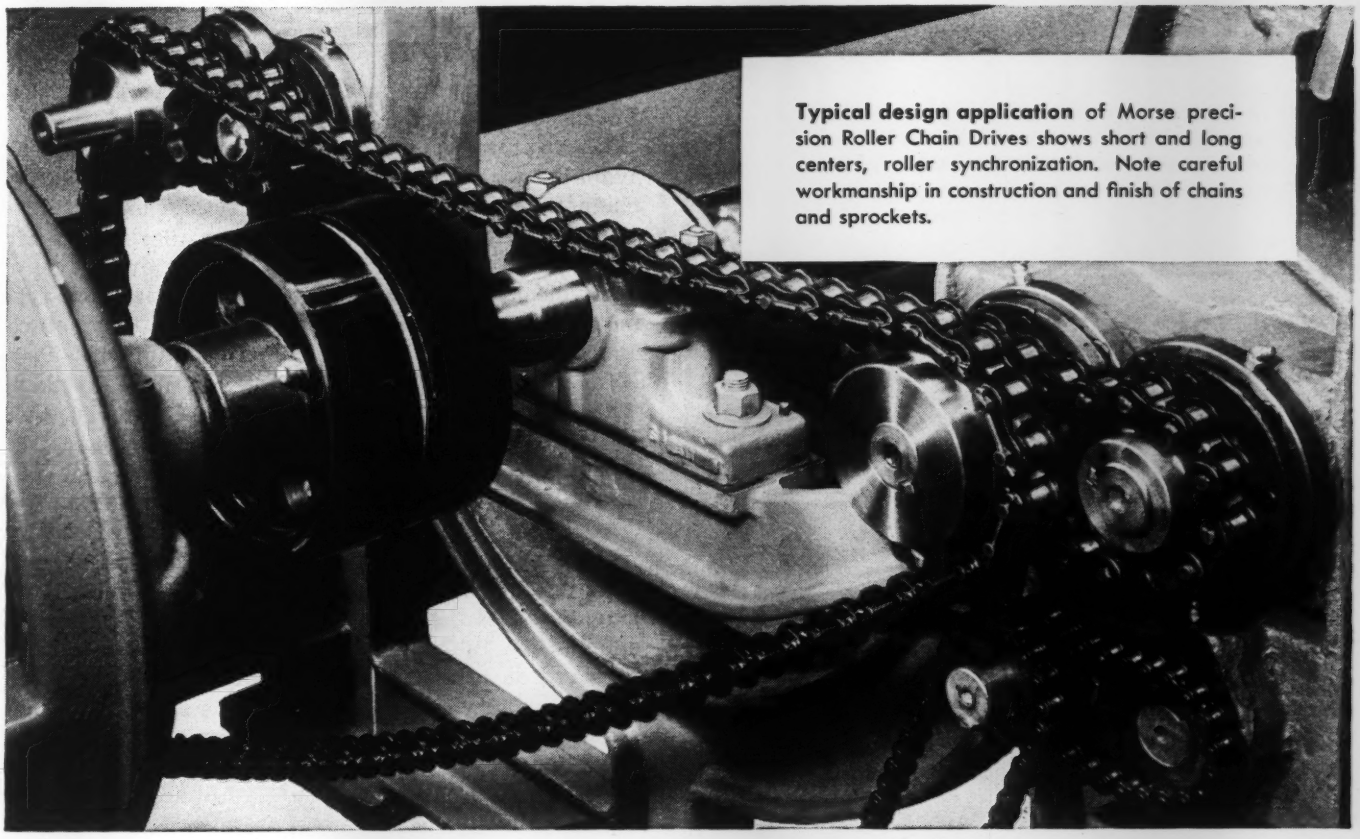
Economical as compared to other variable speed transmissions. Instant adjustment over wide range of speeds. Hand wheel or lever control. Ratios to 10 to 1. Fractional to 5 hp.

UNIVERSAL JOINTS:

Precision ground. Finest alloy steel. No binding, backlash or end play. 13 sizes. Diameters ½ to 4 in. Bores ¼ to 2 in. Lengths 2 to 10⅝ in.

LOVEJOY FLEXIBLE COUPLING COMPANY

4818 W. Lake St. • **Chicago 44, Illinois**



Typical design application of Morse precision Roller Chain Drives shows short and long centers, roller synchronization. Note careful workmanship in construction and finish of chains and sprockets.

Get nearly 99% efficiency throughout the long life of your drives

Whether your problem is transmitting fractional or extremely heavy horsepower, Morse precision Roller Chains and Stock Sprockets can help you.

Morse precision Roller Chains are noted for excellent workmanship and accuracy, resulting in long, trouble-free service life. There is positive power transmission with Morse precision Roller Chains, with *nearly 99% efficiency throughout their entire life.* Coupled with Morse Stock Sprockets, they make an excellent power transmission team; one which reduces both downtime and maintenance.

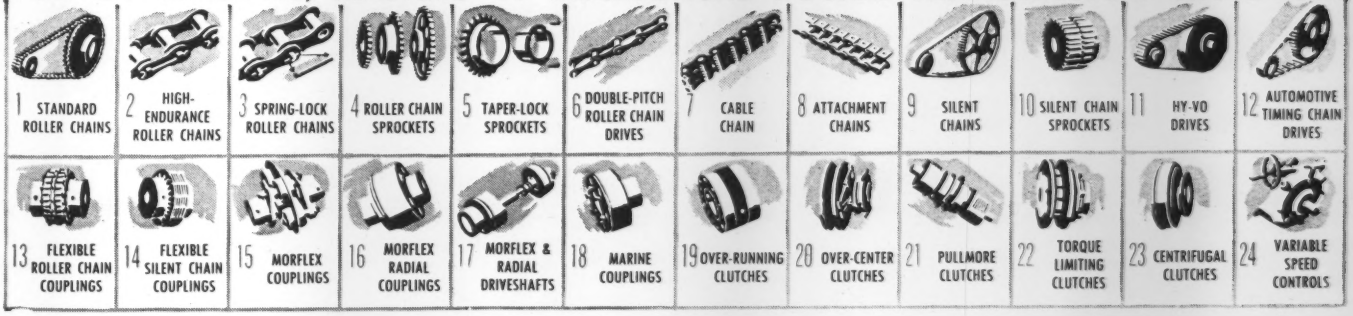
Rollers on Morse precision Roller Chains are shot peened and heat treated for maximum strength and endurance. They are held to close limits to provide even distribution of the load.

When Morse precision Roller Chains and Stock Sprockets go to work, you gain in off-the-shelf service and design flexibility. Morse precision Roller Chains save space by transmitting more usable power than many other types of power transmission drives. They operate equally well on short or long centers, and mesh with sprockets on either side of the chain to drive multiple sprockets for accurate timing. You realize production economies through greater permissible center distance tolerances and greatly increased ease of assembly.

Be sure to call in your Morse sales engineer on *every* power transmission problem. He is a qualified power transmission specialist and can bring the latest information and specialized engineering aid to you. Write us today for further information. MORSE CHAIN COMPANY, 7601 Central Ave., Detroit 10, Michigan.

MORSE
MECHANICAL POWER TRANSMISSION PRODUCTS

FOR 24 REASONS, MASTERS OF MECHANICAL POWER TRANSMISSION SINCE 1893



PULSOLATOR

The Automatic Lubricator that can be
400 places at once
as often as 20 times a minute

Yes, Pulsolator can dependably lubricate as many as 400 bearings with a controlled quantity of oil, as frequently as 20 times a minute, through a single system with loop line up to 300 feet.

Here is your answer to reliable, automatic lubrication for machine tools, printing presses and similar equipment where the higher pressures of force feed systems are not essential. Pulsolator can save you money by eliminating oil waste and repairs and down time that come from lubrication failures resulting from human oversight or neglect.

Systems with various capacities and with both gravity and pressure feeds are adaptable to an endless variety of applications. Let experienced Manzel engineers show you how Pulsolator automatic lubrication can lower your costs and speed production efficiency. Write:

Manzel

DIVISION OF FRONTIER INDUSTRIES, INC.
276 BABCOCK STREET BUFFALO 10, N. Y.

New Machines

42-in. forks, truck turns in 83-in. intersecting aisles. *Elwell-Parker Electric Co., Cleveland, O.*

Electric Hoist: Type J-3 electric wire-rope hoist, available with either single or two-speed pushbutton magnetic control, has rated capacity of 2 tons. Lift is 18-ft without overwind; overwinding allows 25-ft lift. Upper and lower limit switches prevent overtravel of hook block in either direction. Magnetic, disk type motor brake automatically opens when hoist starts and closes instantly when current is shut off. Powered by 2-hp ball-bearing motor, hoist is available with plain, hand-geared or motor-driven trolley. *Robbins & Myers Inc., Springfield, O.*

Metalworking

Semiautomatic Grinder: Type CM-1 heavy-duty machine grinds multiple diameters simultaneously in a single automatic plunge-grind cycle. Heavy wheel spindle has 12-in. body diameter and is supported at each end in cartridge type bearings. Multiple wheels 36 in. in diameter are carried on the spindle body between bearings to a maximum overall span of 30 in. including spacing collars. Wheel head moves on widely spaced 74-in. ways. Hydraulically operated wheel-truing device consists of individual units for each grinding wheel; truing of all wheels is done simultaneously. Compensation for wheel diameter reduction is automatic. *Norton Co., Worcester, Mass.*

Multiple-Purpose Machine: Kitchen & Wade horizontal drilling, boring, milling and tapping machine has spindle which measures 2½ in. at its smallest diameter and will feed out 30 in. It operates at 36 speeds, from 8½ to 800 rpm. Eight rates of power feed from 36 to 150 cuts per inch are provided. Large friction clutch on saddle permits stop, start and reverse at any speed. All locking motions are operated on the saddle also, and an automatic trip is provided for depth drilling. Drills from the solid in mild steel and bores up to 24-in. diameter. Also available with 1½ to 4-in. spindle sizes. *British Industries Corp., International Machinery Div., New York, N. Y.*

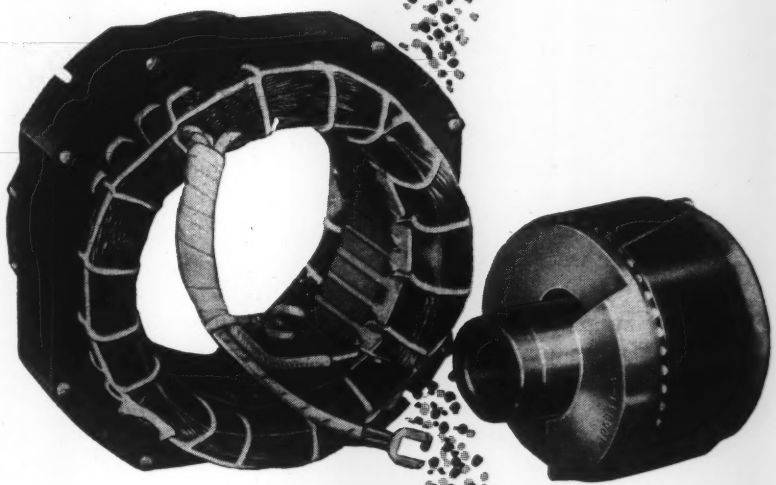
Press Brake: Semco model 800 has one-piece machine frame normalized to relieve strain and insure accuracy. Delivers from 16 to 40 strokes per minute. Bending capacity is 96 in. in 16 gage material. Other specifications include overall height, 79 in.; overall depth, 44 in.; width at base, 64 in.; distance from floor to bottom of throat, 30½ in.; stroke, 3 in.; ram adjustment, 4½ in. *Service Machine Co., Elizabeth, N. J.*

Tube Bending Press: With 20-ton hydraulic power, machine bends ½ through 2-in. OD steel tubing with maximum wall thickness of 0.083-in. Clearance is provided to bend a 2-in. tube with 5-in. centerline radius through an angle of 180 degrees. Ram cylinder with 12-in. stroke is operated with circuit which automatically doubles the down speed whenever work requires pressure less than 10 tons. Ram speed under no load and on return stroke is double working speed. Twin double-acting equalizing cushions are mounted on sides of press, direct connected to needle-bearing

lonesome part of a popular product

The hermetic motor—that part of a modern refrigerating unit the user *never* sees—is truly "out of sight . . . out of mind."

And the fact that it is forgotten is a tribute to its design and construction, for here is a motor that must always function perfectly, while permanently enclosed in the compressor housing. *The "forgotten" part of many of America's most dependable refrigeration units is an Emerson-Electric Hermetic Motor.*



You can benefit from Emerson-Electric's 63 years of experience in motor design and production. If you have requirements in ratings from 1/20 to 5 h.p., or hermetic motors from ⅛ to 20 h.p., Emerson-Electric has the right motor for you. Your inquiry is invited.

THE EMERSON ELECTRIC MFG., CO.
St. Louis 21, Mo.

Write for these Emerson-Electric Motor Data Bulletins

Manufacturers requiring motors 1/20 to 5 h.p. can profitably use these reference guides. Specifications, construction and performance data are included for these motors:

- ☐ 497-A Capacitor-Start
- ☐ 497-B Split-Phase
- ☐ 497-C Integral
- ☐ 497-D Fan-Duty
- ☐ 497-E Oil-Burner
- ☐ 497-F Jet Pump
- ☐ 497-G Blower

EMERSON ELECTRIC
MOTORS • FANS APPLIANCES

Versatile pin does 4 jobs in a great new product!

SPIROL PIN — a pivot, a stop, a fastener and a reinforcement in the new DICTAPHONE Time-Master '5'

Engineers who designed Dictaphone Corporation's new dictating machine — "Time-Master 5" — found the new SPIROL pin so versatile that it could be used as a *pivot*, as a *stop*, as a *fastener*, as a *reinforcement* . . . a pin whose radial spring action would hold fast, yet could be easily removed without damage to either fastening or hole.

1. **SPIROL pins pivot** plastic control button and swinging microphone hook. SPIROL's all-around tension fits snugly in a *molded* hole in the plastic assembly, eliminating all drilling and reaming operations.

2. **SPIROL pin fastens** guide rod to frame. When compressed by insertion, pin exerts even *radial pressure* with no weak "hinge" lines — provides for easy removal and reinsertion in the field without damage to pin or hole.

3. **SPIROL pin reinforces** as well as fastens frame. Extends deep into frame, adding strength. Replaces more expensive dowel, saves a reaming operation.

4. **SPIROL 'stop'** controls movement of cam, absorbs shock better than solid pins. Available in standard sizes from 1/32" to 1/2" dia. and 1/8" to 4" length, or to specification.

Write for illustrated folder and sample SPIROL pins.

SPIROL PIN

C. E. M. COMPANY • 68 SCHOOL ST. • DANIELSON, CONN.

New Machines

mounted crank arms of wing die holders. Three anchor positions compensate for various settings, and pressure is adjustable from ½ to 15 tons. Die holders are forward mounted and equally controlled with single screw adjustment and die recesses. Machine has 10-position angle-of-bend selector with automatic index. Powered by 20-hp, 1200-rpm motor which operates on 220 or 440-v, three-phase 60-cycle current. *Pines Engineering Co. Inc., Aurora, Ill.*

Multiple Drill: Semiautomatic, hydraulically controlled machine drills closely spaced holes. Consists of two vertical structures mounted opposite each other; table is traversed on the base between these two structures. Power heads with integral hydraulic feeds mounted on each vertical structure can feed individual drills or drill heads at varying speeds into opposite sides of work at different levels. Heads, designed to resist 23,000-lb unbalanced thrust loads, are positioned vertically by twin hydraulic cylinders that are guided on two columns. *Walter P. Hill Inc., Detroit, Mich.*

Metal Saw: Two-speed V-belt driven machine for general purpose use has 6 x 6-in. capacity. Trip switch automatically stops the motor, disengages feeding mechanism at the completion of each cut and allows the frame to raise automatically to starting position. Compensating feeding mechanism adjusts to size and shape of work; fine adjustments for varying pressures are made with feed adjusting handwheel, pressure indicator and graduated scale. Adjustable gibs on top and side of saw frame guide compensate for wear. *Peerless Machine Co., Racine, Wis.*

Hydraulic Metal Cutter: Model 21 guillotine cutter supplies 50 tons cutting thrust through a hydraulic pump powered by a 2-hp motor. It cuts 1¼-in. diameter steel rod in 3½ seconds and aluminum rod to 1⅝ in. in diameter. Unit can be obtained dolly-mounted with the cutting head suspended by a spring tension balancer. Cutting head weight is 150 lb; total weight of unit, including carriage, 921 lb. *Manco Mfg. Co., Bradley, Ill.*

Internal Burring Machine: Model 388 is designed for chamfering the involute contour of internal spline and gear teeth, either straight or helical, around their full form. Production rate, depending upon diameter and pitch of gear teeth, is up to 300 teeth per minute. Machine can be changed over from one type of gear to another in less than 30 minutes. *Sheffield Corp., Dayton, O.*

Heavy Presses: Line of mechanically operated Wickliffe presses perform such operations as forming, blanking, piercing, trimming, light embossing and drawing. Straight-sided frames consist of four members: crown, two side housings and bed. Barrel type slide adjustment provides stability. Cool operation of clutch and brake is facilitated by low unit working pressure on clutch and brake facings, low inertia of clutch and brake disks which minimize energy to be absorbed, hollow center ventilating disks which have large cooling passages, and overall design for fast heat dissipation. Single, two and four-point single-

DELCO MOTORS

the best running mate your product can have

Millions of Delco Motors—fractionals and integrals—are giving reliable service in the operation of farm equipment, home appliances, tools and machinery of every sort.

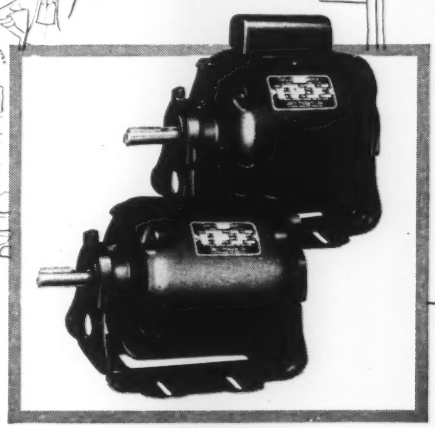
Such wide usage suggests that Delco Motors give a good account of themselves, performance-wise. Such user acceptance suggests, too, that you would find a Delco Motor the best running mate for *your* product.

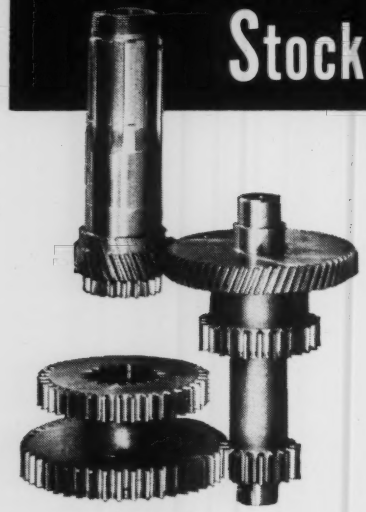
DELCO PRODUCTS

DIVISION OF GENERAL MOTORS CORPORATION
DAYTON 1, OHIO

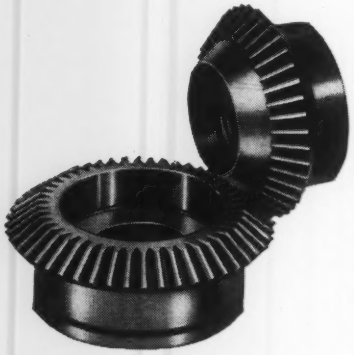
SALES OFFICES:

Atlanta • Chicago
Cincinnati • Cleveland
Dallas • Detroit
Hartford • Philadelphia
St. Louis • San Francisco





• For Forty years Ohio Gear engineers and craftsmen have enjoyed an unusual reputation for turning specifications into power transmission of highest industrial quality.

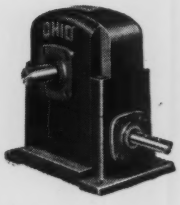


Ohio gears are produced by the most modern equipment and methods in gear cutting. Complete up-to-date machinery operates throughout the plant... cutting, broaching, milling, drilling, heat treating and grinding.

Ohio Gear specializes in Spur, Bevel, Miter, Helical, Worms and Worm Gears, Sprockets, and Spline Shafts.

We will be glad to assist you in your gear production problems and quote on your specifications.

DISTRIBUTORS IN PRINCIPLE INDUSTRIAL AREAS



THE OHIO GEAR COMPANY
1338 East 179th Street · Cleveland 10, O.

OHIO GEARS

New Machines

action presses are included in line. *Cleveland Crane & Engineering Co., Wickliffe, O.*

Portable Tools

Grinder: Super-10 Handgrinder, used for close finishing work, operates at speeds up to 22,000 rpm, using vitrified wheels up to 1 in. diameter. Overall length, including chuck, is 10¼ in., body diameter is $2\frac{7}{16}$ in., and small diameter is $1\frac{5}{16}$ in. Tool weighs about 3 lb and is powered by a 1/10-hp continuous duty rated 115-v ac-dc universal motor. *Dumore Co., Racine, Wis.*

Flat Angle Drill: Model 7438 pneumatic unit for drilling in close quarters or on hard-to-reach work has 43/64-in. head height, $\frac{5}{16}$-in. spindle offset and $10\frac{5}{16}$ in. overall length. Heavy-duty bevel gears are at rear end of housing. Precision gears in angle-head are mounted on needle bearings. Right-angle assembly is fabricated from ductile iron. Tool components are interchangeable for speed conversion, and models are available with speeds of 1450, 2100, 2500 and 4000 rpm. Threaded spindle accommodates threaded drill bits, and small external collets are available for numbered drill sizes up to ¼-in. *Aro Equipment Corp., Bryan, O.*

Grinder: Pencil grinder which operates at speeds up to 100,000 rpm has safety guard which fully encloses the chuck nut. It etches, grinds, polishes and deburrs. Grinder measures ⅞ x 4¼ in.; weighs 5 oz. *Nu-Jett Products, Grand Rapids, Mich.*

Pneumatic Tools: No. 3 series of air tools includes a model with four straight drills which are convertible to direct drive nut setters, four right-angle drills and four right-angle nut setters. Speeds range from 3400 to 800 rpm with capacities of ¼, 5/16 and ⅜-in. No. 35 series includes three grip-handle drills with speeds of 1150, 800 and 550 rpm and capacities of ⅜ and 7/16-in. Drills are convertible to direct drive nut setters of 5/16-in. thread size capacity. No. 5 series consists of right-angle nut setters with speeds of 600, 450, 300 and 225 rpm for setting nuts of ½, ⅝ and ¾-in. thread size. *Thor Power Tool Co., Aurora, Ill.*

Testing and Inspection

Heavy-Duty Crane Scale: Model 16-10000DH spring type dynamometer crane scale has capacity of 10,000 lb calibrated in increments of 25 lb. Readings are made directly from 15-in. diameter dial. Equipped with four precision calibrated alloy-steel springs which act as force measuring element and absorb shock. Has 10 per cent tare adjustment and ball-bearing swivel hook to shorten overall length of 36.5 in. Extension at capacity is 1.208-in. Scale weighs 240 lb. *John Chatillon & Sons, New York, N. Y.*

Gear Checker: Measures gears of 20 pitch and finer in sizes up to 4-in. pitch diameter, external or internal. Operation is based on principle that errors in gear tooth elements are likely to cause changes in center distance. Master gear is mounted on an arbor in a movable spring-loaded carrier and can be rotated

WHEN YOU THINK OF SEAMLESS DRAWN METAL STAMPINGS THINK OF G. P. & F.

15 ACRES OF PRODUCTION FACILITIES • OVER 1000 SKILLED PEOPLE

You can end production headaches, increase manufacturing profits, and sell quality-built products, by using G. P. & F.'s complete fabricating and finishing service. Scores of America's leading firms use and recommend our service for hundreds of highly diversified items—including everything from parts for automobiles to home appliances—or from coin-operated dispensers to office equipment.

WE FINISH AND ASSEMBLE - - - We can handle your *complete* job—from start to finish. We specialize in medium and large sized seamless drawn metal stampings—but our service also includes forming, welding, galvanizing, polishing, vitreous enameling, spray painting, and complete assembling.

ALL UNDER ONE ROOF - - - - - Not only do we relieve you of production details and responsibilities, but we also increase your profits by reducing shipping time and transportation costs on your contracted parts. All work is done under one roof in our centrally located Milwaukee plant. And, if you wish, we can package your products, and ship directly to your customers!

G.P.&F. SINCE 1880 MILWAUKEE

GEUDER, PAESCHKE & FREY CO.